The
ENGINEERS' DIGEST

A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXI No. 7 JULY, 196

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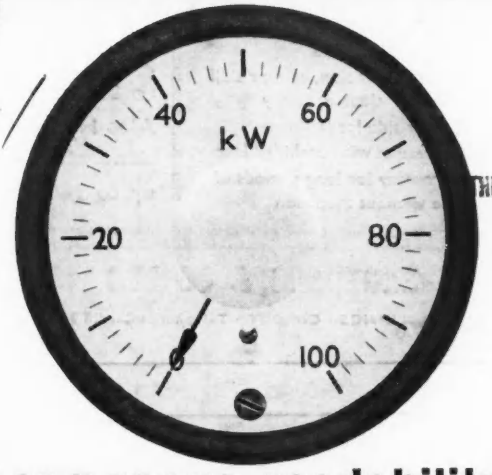

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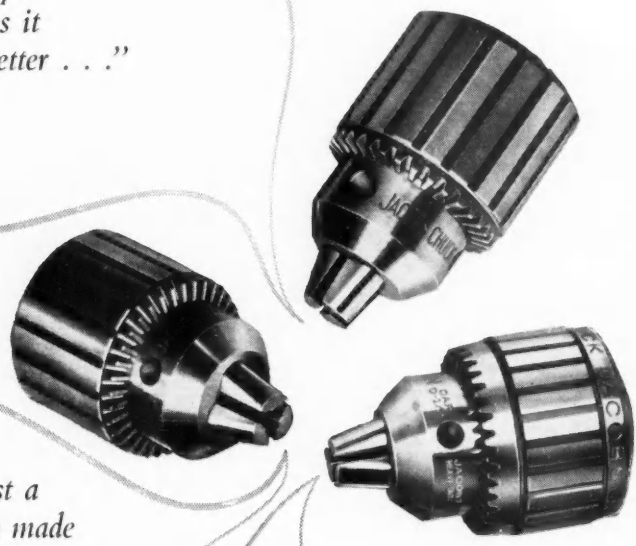

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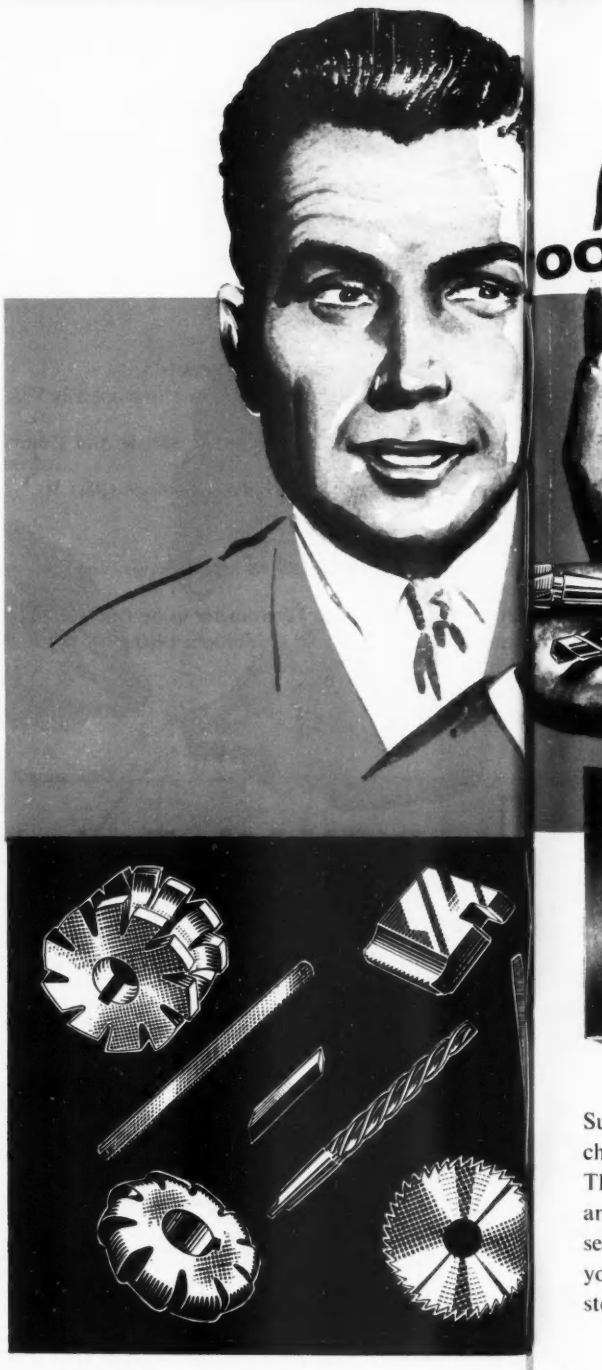
As reported briefly in *Product Engineering* for June 13, 1960, two new types of **high-voltage, high-energy storage capacitors** are under development by two American companies. Of these, one type comprises storage capacitors with an insulation resistance of 10 megohm-farads, capable of operating at 930°F and 1000 V d.c. in the presence of high-flux radiation fields. These capacitors, which should be available shortly on a production basis, use boron nitride, hot-pressed on gold-plated iron electrodes, as the dielectric and are designed to be enclosed in an alumina housing packed with alumina powder. The other type comprises ultrathermic 5-megohm-microfarad capacitors for operation at temperatures up to 930°F. These capacitors, which are in an advanced stage of development, use high-purity alumina, flame-sprayed on aluminium electrodes, as the dielectric. Similar designs, using magnesia and boron nitride as the dielectric, are also under test.

* * *

An article in *Inzhenierno-Physicheskyi Zhurnal* for April 1960 gives details of recent studies carried out in Russia in connection with the character of the **crystalline transformation of sintered nickel-copper** specimens. With these specimens, which contained 70% nickel and 30% copper, it has been established that, when sintering commences, in the temperature range between 100° and 400°C, no substantial changes in character occur. At a temperature exceeding 400°C, the reduction of oxides is initiated, followed by recrystallization of metal particles. After 500°C, formation and homogenization of the Cu-Ni solid solution begins, accompanied by grain growth and an increase in the volume of the specimens, formation of the sintered metal being virtually completed at 1000°C.

* * *

The results of research carried out in England by the Wakefield Castrol Group have indicated that a possible **cause of the corrosion of white-metal bearings in marine steam turbines** is stray electric currents, possibly derived from the increasing use of electrical and electronic equipment, including radar. A major component of the corrosion product is tin oxide and, while it is true that electrolytic corrosion of tin in a normal tin/steel system will not occur, since steel would be the anode, it has now been found that, by applying a low electrical potential (1·5 V) to a white-metal/steel combination im-



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The MINIDIGEST

mersed in a very weak salt solution, the arrangement can be reversed, i.e., the white metal is transformed into the anode. In fact, in laboratory experiments, a corrosion layer, 0·0015 in. thick, has been produced in this way in a period of 40 hr, and has been found to be identical with that occurring in service. Alternating current produces a similar effect, but at a very much slower rate.

* * *

It is reported in *The Journal of the Institution of Electrical Engineers of Japan* for February 1960 that, by virtue of an **improved method of producing indium antimonide Hall generators,** in which indium antimonide is evaporated from a molybdenum boat in a vacuum of approximately 10^{-4} mm Hg onto thoroughly cleaned glass or mica plates preheated to between 240° and 260°C, it is possible to produce generators of this type with a Hall coefficient about fifty times higher and a mobility several hundred times higher than can be obtained by conventional methods. In addition, with this new method, which was developed at the Tokyo Institute of Technology, these Hall generators can be manufactured in any shape and thickness, whereas Hall generators produced from single-crystal semiconductors are normally limited in size.

* * *

Intended to minimize the potential hazards incurred by the presence of water in oil-quench tanks, a simple **instrument for detecting small quantities of water in oil** has been developed in the U.S.A. by Ipsen Industries, Inc. This new safety device (reported briefly in *Metal Progress* for May 1960) essentially consists of a probe containing a replaceable resistor sensitive to water, the probe being immersed in the oil and sealed in the tank. When the amount of water in the tank exceeds 0·1%, an alarm is actuated, or the unit is automatically shut off.

* * *

Details of recent experiments carried out at the University of Louvain in connection with the **ionization characteristics of hydrogen-oxygen flames** are summarized in *Bulletin des Sociétés Chimiques Belges* (No. 1–2, 1960). In these tests, sodium salts or increasing amounts of acetylene or methane were introduced into hydrogen-oxygen flames diluted with nitrogen, and the degree of ionization measured. It was found that the addition of only a small amount

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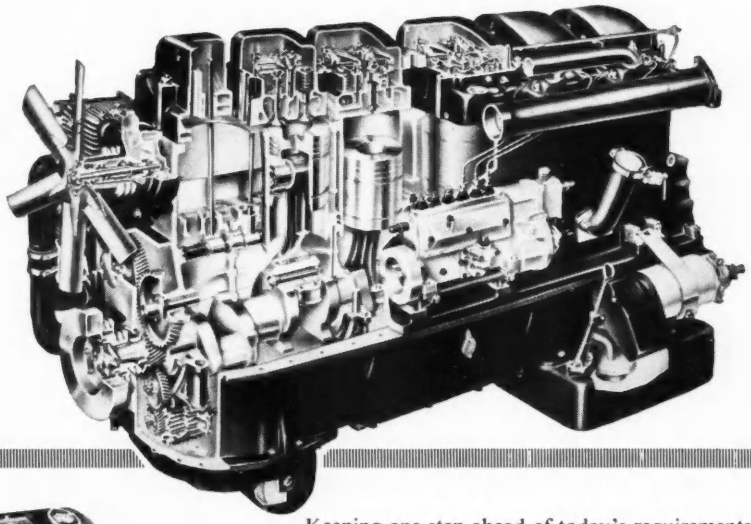

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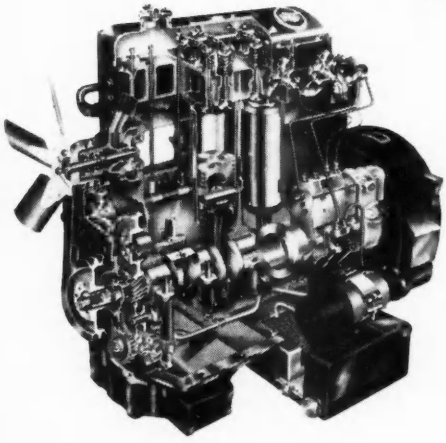

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The MINIDIGEST

of acetylene or methane is conducive to abundant ionization, the degree of which is in this case much higher than would be expected from the theoretical thermal equilibrium of the gases. However, when sodium salts are introduced into the flame, ionization occurs in strict accordance with the law of energy equipartition, although the concentration of ions is greater in the combustion zone than in the burnt gases.

* * *

According to an investigation carried out in Germany and reported in *Werkstoffe und Korrosion* for March 1960, it appears that there is considerable doubt regarding the suitability of the ferroxyl test for determining the **corrosion resistance of nickel coatings.** The investigation shows that, with thin nickel coatings, so many blue spots appear on the surface of the specimens that there is no point in counting them, while, in the case of coatings which are thicker than 12 microns, the test is unreliable for determining porosity for various reasons, including the fact that it is very difficult to reproduce, even when the test conditions are laid down in great detail.

* * *

According to a note in *Machine Design* (May 26, 1960), it is possible to effect **damping of vibration in aircraft skins by magnetism.** If the field of a permanent magnet attached to the frame of the aircraft is arranged to envelop an aluminium ring fastened to a panel or section of the skin, then the ring will move backwards and forwards in the field of the magnet when the panel vibrates. As a result, an electric current is caused to flow in the ring, and this current reacts with the magnet to stop vibration.

* * *

According to a report in *Yogyo Kyokai Shi* for February 1960, superior types of **devitrified ceramics** have been produced in Japan by a two-stage heat treatment of special glasses made from various percentages of mica and spodumene. In the first stage, the glasses are heated to slightly above their exothermic temperature for 2 hr, and, in the second stage, to 950°C for 1 hr and subsequently to 1000°C for 2 hr. It is stated that optimum results have been obtained with a mixture containing 75% mica and 25% spodumene, which, after this heat treatment, gave a ceramic composed of submicroscopic crystals with a uniform texture and extremely high mechanical strength.

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BUSINESS NOTES

Ether Langham Thompson Ltd., of Stevenage, Herts, announce the formation of a new subsidiary company, **Ether Langham Thompson (Italiana) Ltd.,** with offices and factory at Via Bisleri 19, Milan, Italy, who will market and manufacture products of the subsidiary companies of Ether Langham Thompson Ltd., i.e., **Ether Limited, J. Langham Thompson Ltd., Electro Methods Ltd., Datum Metal Products Ltd.,** and **Automation Systems & Controls Ltd.** In addition, agency agreements have been completed between the Italian company and a number of other well-known British and international companies engaged in the field of instrumentation.

* * *

It is announced by the **Elgar Machine Tool Company Ltd ,** of 172-178 Victoria Road, Acton, London, W.3, that they have been appointed exclusive distributors in the U.K. for the complete range of hydraulic horizontal and vertical broaching machines manufactured in Italy by **Varinelli,** of Milan.

* * *

Burton, Griffiths & Co. Ltd. (B.S.A. Tools Division) announce that their address is now 54 St. James's Street, London, S.W.1. The telephone number is HYDe Park 3575, and the Telex number 25711.

* * *

Sciaky Electric Welding Machines Limited, of Slough, in association with **Pye Industries Limited,** announce the formation of an Australian company, called **Sciaky Australia (Pty.) Limited,** who will manufacture, install, and service resistance-welding equipment for the Australasian Continent. A new factory is in course of construction at Fairfield, New South Wales, and is expected to be in production in the very near future The directors of the new company include Mr. R. W. Ayers (U.K.) and Mr. David Sciaky (U.S.A.).

* * *

It is announced by **Richard Sutcliffe Limited,** of Horbury, manufacturers of mechanical-handling equipment, that they have formed a subsidiary company, **Sutcliffe Plant Hire Limited,** the object of which is to provide a hire or hire-purchase service for conveying and associated ancillary equipment. The offices of this company are at 14a Bond Street, Wakefield, Yorks. (Tel.: Wakefield 6433).

* * *

The **Elgar Machine Tool Company Ltd.,** of Acton, London, W.3, have been appointed exclusive distributors in the U.K. of the range of vertical and horizontal injection-moulding machines manufactured in Germany by **P. Flesch,** of Ludenscheid.

* * *

An agreement signed between **The General Electric Co. Ltd. of England** and **The British-Geco Engineering Co. Ltd.,** of Edenbridge, Kent, covers the design, manufacture, and sale of all types of induction-heating plant for ferrous and non-ferrous metals, combining the

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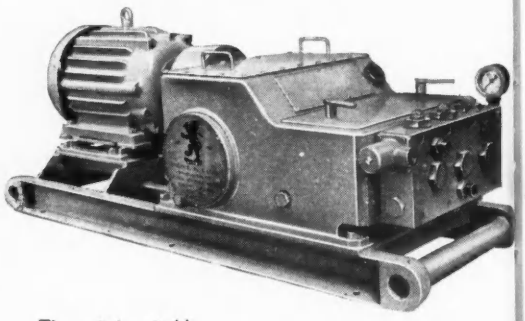

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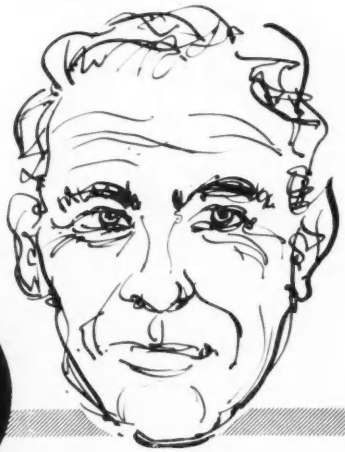

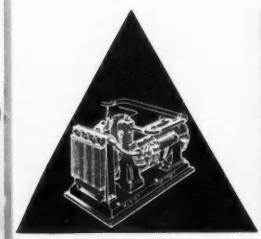

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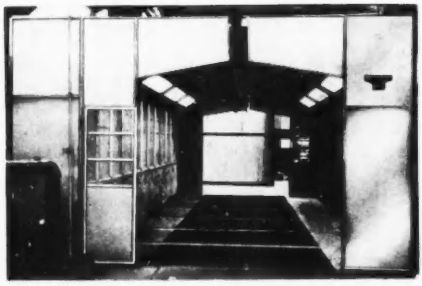

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BUSINESS NOTES

expert knowledge and resources, including extensive facilities for research and development work, of both companies in all matters relating to induction heating. Enquiries for induction-heating plant covered by the agreement, as well as requests for information, should be addressed to the Furnace Department, The General Electric Co. Ltd., Erith, Kent.

* * *

Baker Perkins Ltd., of Peterborough, have acquired the **Granbull Tool Co. Ltd.,** of Kingston-on-Thames, Surrey, and Twickenham, Middlesex, manufacturers of moulds and equipment for the plastics industry and of press tools, jigs, and fixtures for industry generally.

* * *

It is announced by **Head Wrightson Colliery Engineering Limited,** a subsidiary of **Head Wrightson & Company Limited,** of Thornaby-on-Tees, that the company's name has been changed to **Head Wrightson Minerals Engineering Limited.**

* * *

Hamworthy Engineering Limited, of Poole, Dorset, have purchased **Schieldrop and Company,** of Stotfold, Beds., manufacturers of industrial oil-burning equipment for kilns and furnaces. Schieldrop and Company will continue to trade as a separate entity, and Mr. I. P. Frost will continue as managing director. The Schieldrop range of oil-burning equipment is complementary to the Hamworthy range and will considerably broaden the latter company's oil-burning interests.

* * *

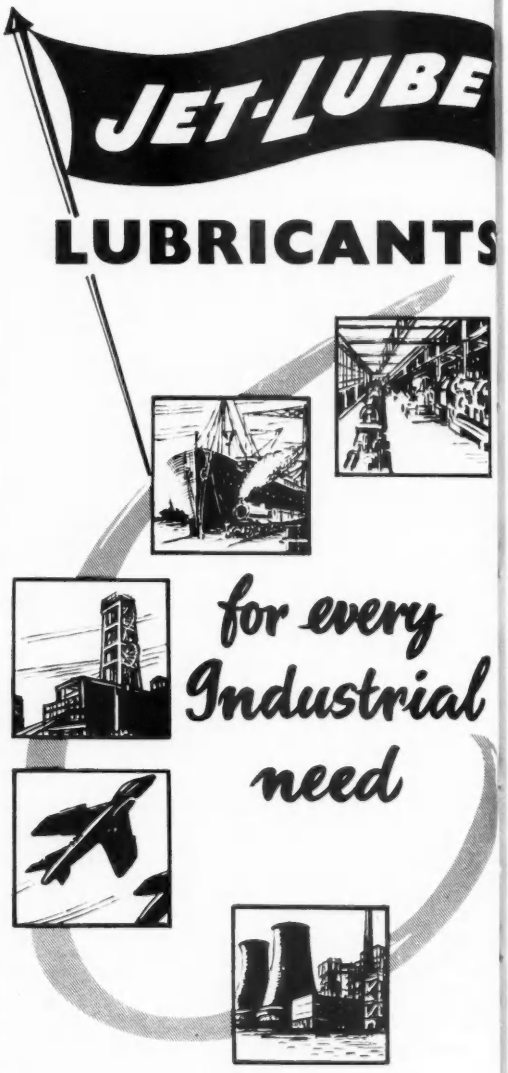
It is announced by **Elliott-Automation Limited,** of London, W.1, that they have entered into an agreement with **Hallikainen Instruments,** of Berkeley, California, under which they will exploit the range of automatic analytical control instruments developed by the **Shell Research Laboratories,** at Emeryville, Cal., for the petroleum, petrochemical, and chemical industries, and manufactured under licence by Hallikainen, who will supply the North and South American markets and Japan, and Elliott-Automation the rest of the world. A new Elliott-Automation subsidiary company, **Hallikainen Instruments Limited,** is being formed in London to handle this new business.

* * *

As a result of further discussions between **Atomic Power Constructions Limited** and the **G.E.C. Simon-Carves Atomic Energy Group,** these two companies have now agreed to join forces for the design and construction of nuclear power stations in Great Britain.

* * *

It is announced by **Dymet Alloys Ltd.,** who specialize in the production and manipulation of tungsten carbide, that they have now moved from Croydon to their new address in Frimley Road, Camberley, Surrey (Tel.: 4433/4). Dymet is an associated company of **Rockweld Ltd.,** who will also move to Camberley later this year.



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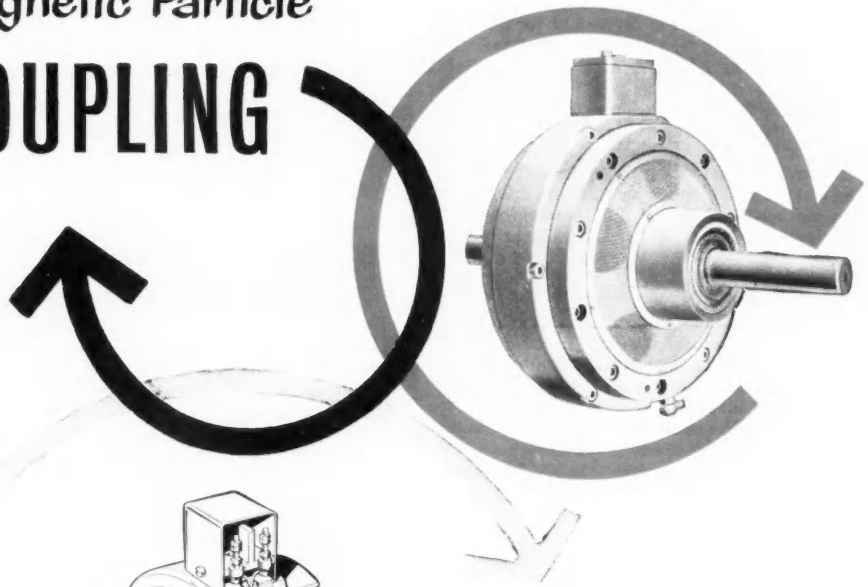
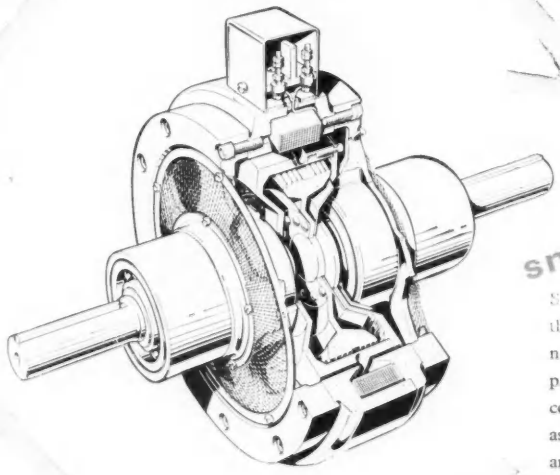
SMITHS

Magnetic Particle
COUPLING





smooth yet positive

Smooth as a hydraulic coupling, but without the drag, positive as a friction clutch but never needing adjustment for wear, SMITHS magnetic particle COUPLING provides accurate control of torque without complications. It acts as a coupling or brake in either direction and can be remotely controlled from any distance.

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SMITHS

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INDUSTRIAL PRODUCTS DEPARTMENT, WITNEY, OXON. Telephone WITNEY 678

AP 92

CONTRACTS

The General Electric Co. Ltd., in association with Vacuum Industrial Applications Ltd. and the British Geco Engineering Co., has secured an order, approaching £100,000 in value, from Jessop-Saville Ltd. for the supply of an induction melting furnace of 1-ton capacity. This is believed to be the largest furnace of its type being manufactured in this country and is scheduled for installation in the Company's Brightside Works, Sheffield, by the end of the year. The furnace, which will operate at 1700°C, is designed for semi-continuous operation and has provision for casting under a vacuum. Bulk charging and alloy additions can also be effected without breaking the vacuum. Power will be supplied to the furnace at two frequencies, one of which will be used for heating, and the other for stirring the molten metal.

* * *

Clarke, Chapman & Co. Ltd., of Gateshead, Co. Durham, have been advised by the Central Electricity Generating Board that they have been successful in their tender for the manufacture and erection of steam generating plant, valued at approximately £6,000,000, to be installed at Blyth "B" Generating Station, Northumberland. The installation will consist of two steam generating units, each capable of generating 2,350,000 lb of steam per hour at a pressure of 2400 psi and a temperature of 1055°F.

* * *

The Head Wrightson Machine Company Limited, a subsidiary of Head Wrightson & Co. Ltd., have received an order from Maschinenfabrik Sack, G.m.b.H., of Düsseldorf, for the provision of equipment for a complete billet mill. The value of the contract is approximately £700,000 and includes the intermediate roller tables, cooling banks, and mill drives. The equipment is to be installed at the Redbourn Works of Richard Thomas & Baldwins Limited, from whom Sack have received a contract for the supply of the complete mill. Manufacture of the plant will be completed at the Middlesbrough and Thornaby Works of Head Wrightson.

* * *

An order for diesel-locomotive equipment, valued at £11,000,000, is announced by the British Transport Commission and includes 158 Bristol Siddeley Maybach diesel engines, which are being built by Bristol Siddeley at their Ansty Works, near Coventry, under licence from Maybach Motorenbau G.m.b.H.

* * *

Ferranti Ltd., of Hollinwood, Lancs., announce that they have received from the Central Electricity Generating Board an order valued at approximately £250,000 for a 400-MVA, 3-phase, 50-cps, 380/275-kV auto-transformer for installation at Monk Fryston substation. This transformer is for one end of the transmission line between Monk Fryston and High Marnham, and the transformers at each end of the line will be the largest ever ordered in Europe. Integral high-speed on-load tap-changing gear will also be provided.

Famous for Forgings

The Daniel Doncaster companies never stand still—we are always putting in extensive (and expensive!) new equipment to enable us to undertake by a combination of processes and plant work of the most versatile nature.

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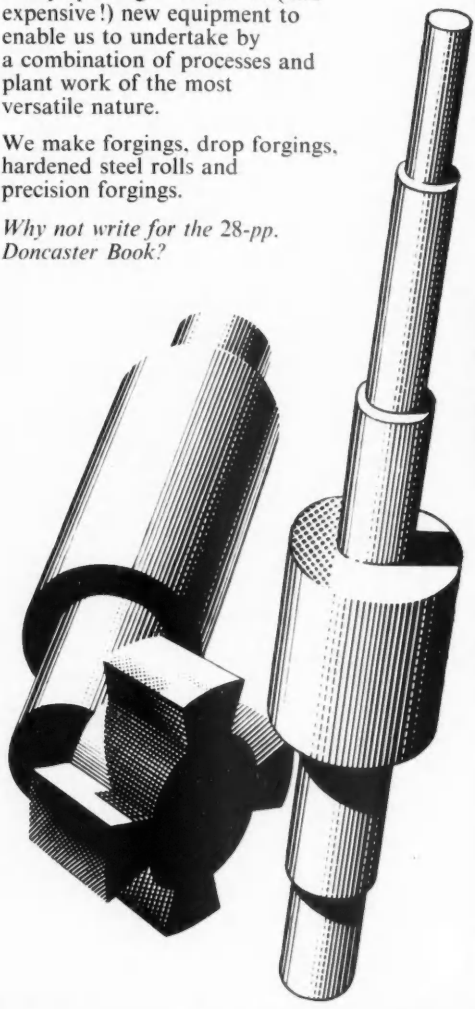

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Slash maintenance costs.
Eliminate special precautions against overloads.
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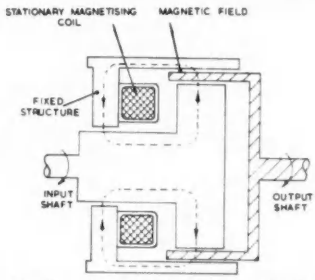

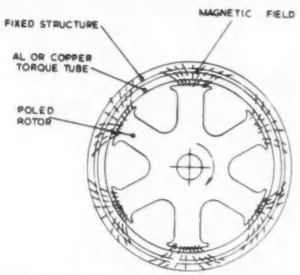

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PERSONAL

Mr. A. C. Ball, B.Sc.(Eng.), A.C.G.I., and **Mr. A. E. Gilbert, F.C.W.A.,** have been appointed directors of Hayward Tyler, a member of the Stone-Platt Industries Group.

* * *

George Ellison Limited, of Perry Barr, Birmingham, announce that **Mr. T. J. Rowlands, B.Sc., A.M.I.E.E.,** has been appointed chief engineer and manager of the Engineering Department of the company.

* * *

Sir James Doak, who has been associated with Fenner's Indian enterprises for a number of years, has joined the board of J. H. Fenner & Co. (Holdings) Ltd., of Hull.

* * *

Humphreys & Glasgow Limited, of London, announce the election to the board of the company of **Mr. R. Langford** and **Mr. I. H. Phillipps. Mr. G. Adams** and **Mr. R. J. Withers** have been appointed associate directors.

* * *

Mr. S. L. Saville, formerly a director of Associated Accessories and sales director of the Talbot Tool Co. Ltd., has been appointed sales manager of John Baker & Sons Ltd., of Sheffield.

* * *

Jessop-Saville (Small Tools) Limited, of Sheffield, announce the appointment to the board of four new directors, i.e., **Mr. J. R. Bottomley, Mr. E. Garlick, Mr. D. Milne,** and **Mr. J. F. Wallace.**

* * *

Mr. N. Fenwick has been appointed sales-promotion manager of W. G. Pye & Co. Ltd., of Cambridge, and will be responsible for all matters connected with advertising and press liaison.

* * *

Mr. W. G. Hadley has joined the Rockwell Machine Tool Co. Ltd. as machine-tool sales engineer, and will operate in the North of England from the company's Stockport office.

* * *

The Engineering Group of The General Electric Company Limited of England announce the appointment of **Mr. E. W. Molesworth** as chief engineer for the London, Southern, and Eastern areas, in succession to **Mr. C. J. O. Garrard,** who was recently appointed assistant general manager of the company's Erith Engineering Works.

* * *

It is announced that **Mr. L. G. Oxford, M.I.P.E., M.I.B.E., A.M.I.W.M.,** managing director of Simmonds Aerocessories Ltd. and of Firth Cleveland Instruments

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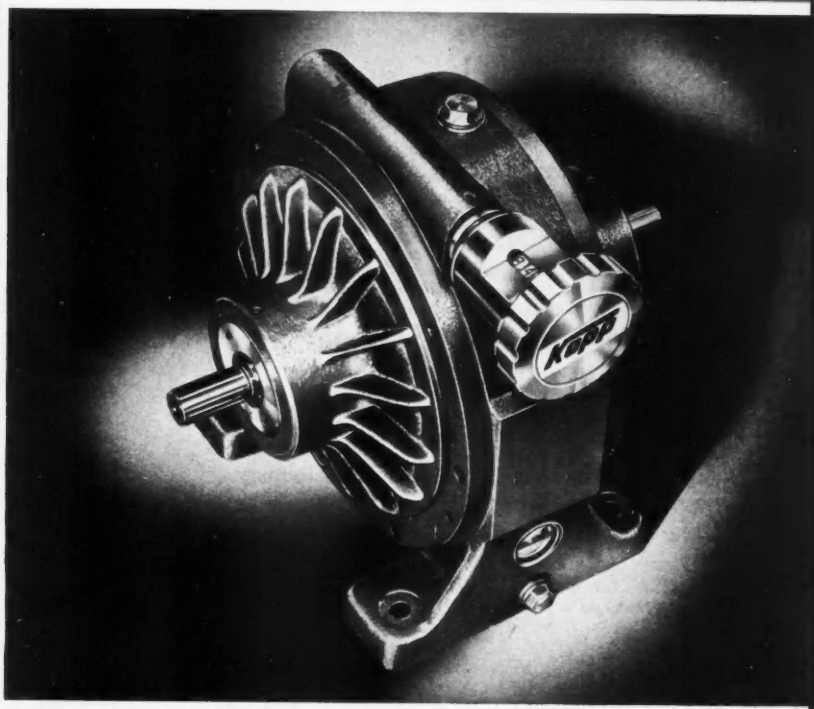

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YORKSHIRE 46 PARK SQUARE, LEEDS, 1 TELEPHONE: 30993

PERSONAL

Ltd., members of the Firth Cleveland Group of companies, has been elected president of the South Wales branch of the National Union of Manufacturers.

* * *

Mather & Platt Ltd., of Manchester, announce that **Mr. J. Martin** has been appointed to the board of the company as head of the Pump Department.

* * *

Worthington-Simpson announce the appointment of **Mr. K. P. H. Jeens** as manager, oil industries department, at their London office in Queen's House, Kingsway.

* * *

It is announced by the Dowty Group Ltd. that **Mr. F. Bastow** has been appointed managing director of Dowty Seals Ltd. and that **Mr. C. F. Porter** and **Mr. K. G. Ware** have been appointed to the board of Dowty Mining Equipment Ltd. **Mr. C. N. King** has been appointed to the Board of Dowty Hydraulic Units Ltd., while **Mr. L. Harper,** formerly managing director of Massey-Ferguson (Great Britain) Ltd., has been appointed managing director of Dowty Hydraulic Units Ltd. and, as such, will undertake the further application of hydraulics and the "Dowmatic" hydrostatic drive in industry and in tractors, combines, and other agricultural equipment. In addition, **Mr. C. Irving,** publication-relations adviser, has now been appointed head of public relations of the Dowty Group, integrating the advertising, press, and publicity departments.

* * *

Plessey International Limited, of Ilford, Essex, announce that **Mr. G. H. Doust** has been appointed general manager.

* * *

The Brush Electrical Engineering Co. Ltd. announce that **Mr. R. L. Oddie, F.C.A.,** has been appointed a director of the company, while **Mr. F. H. Wood, A.M.I.Mech.E., M.I.Loco.E.,** has been appointed executive director.

* * *

Mr. G. Syke, Dipl. Ing., M.I.E.E., has been appointed a consultant to the Physics Department of the British Iron and Steel Research Association, and will be specially concerned with directing the work of the department's instruments section.

* * *

Mr. W. E. A. Redfearn has resigned as chairman of the Alloy Steels Association and is succeeded by **Mr. R. Bavister.** Mr. Redfearn, who has been chairman of the Association for ten years, is a director of the English Steel Corporation Limited and the English Steel Rolling Mills Corporation Limited, and is managing director of the English Steel Forge and Engineering Corporation Limited. Mr. Bavister is a director and commercial manager of Samuel Fox & Company Limited.

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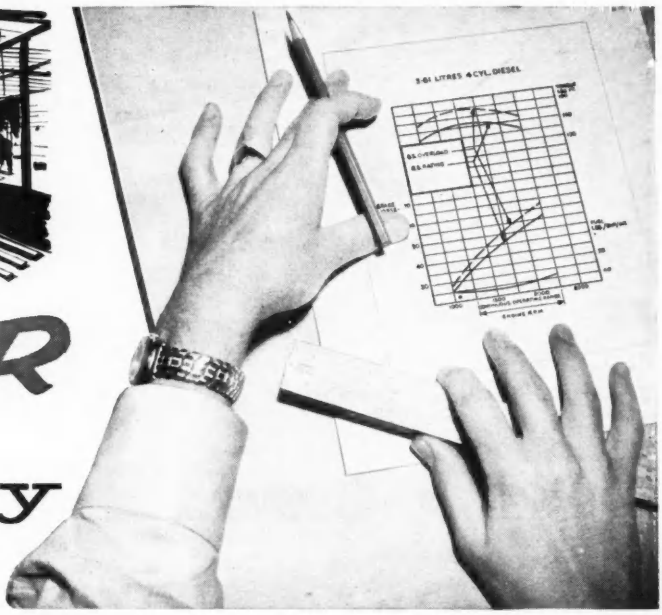

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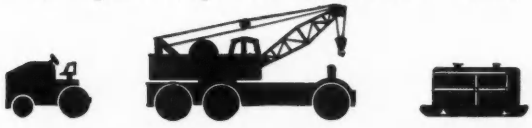

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NEWS ROUND-UP

Four-Strand Continuous Casting Plant

The new four-strand continuous casting plant which Distington Engineering Company Limited are to build and install at the Appleby-Frodingham Steel Company, Scunthorpe, will have the largest productive capacity in the world for a machine of its type. Equipped to cast four strands of blooms, 9-in. square, the Distington machine, designed to operate from 100-ton ladles of steel, with a weekly production capacity of 5000 tons, is scheduled to begin operations in December, 1961.

Liquid steel will be poured from the ladle into a common tundish, with four stopper-controlled nozzles feeding directly into the copper moulds. After leaving the spray cooling chamber, the solidified blooms, withdrawn through pairs of withdrawal rolls, will be cut off vertically into 30-ft lengths, which will be discharged at ground level by means of a discharge conveyor mechanism. The blooms will then be transferred to a new 32-in. reversing mill for rolling into billets to feed the new Appleby-Frodingham rod bar mill, which will have a capacity of 300,000 tons per year of finished products.

Tufnol in the Making

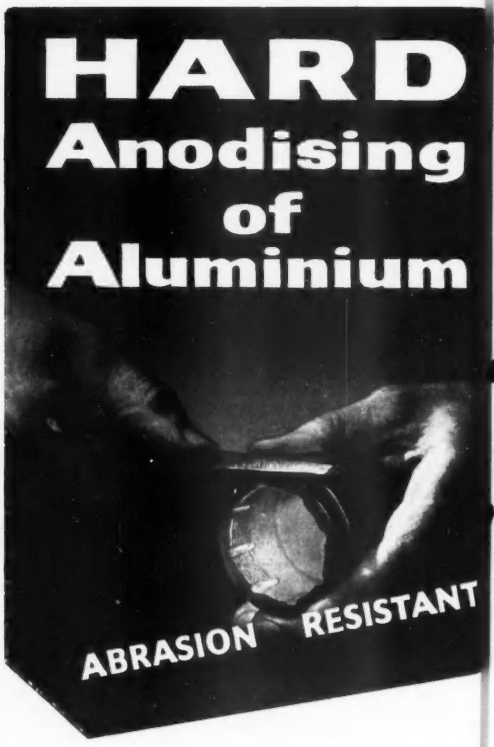
Graphically illustrating the manufacture of Tufnol paper and fabric-base laminated-plastics sheet, tube, and rod, the new film released by Tufnol Ltd., "Tufnol in the Making" starts with the delivery of a consignment of paper and other essential raw materials, and then follows in detail the processing of paper and cotton through the various stages of impregnation, cutting, pressing of sheets, rolling and moulding of tubes and rods, sawing and grinding, and final testing, inspection, storing, and despatch. Particular emphasis is laid on the rigorous testing and inspection taking place from beginning to end to ensure a first-class product.

Copies of this excellent 16-mm sound and colour film, which has a running time of just under 25 min, can be obtained on free hire on application to the Publicity Department of Tufnol Ltd., Perry Barr, Birmingham 22b.

The New Balfour Group Research Centre

Representing a practical approach to the solution of all chemical-engineering problems and providing the widest possible scope and facilities in one compact establishment, the new Balfour Group Research and Development Centre, recently opened at Leven, Fife, comprises a series of modern and well-equipped laboratories for carrying out comprehensive research and development work in connection with the design and operation of chemical process plant. Integrated with the laboratories are comprehensive installations of pilot plant, encompassing the main types of processes and equipment, to demonstrate applications on clients' raw materials. As a result, complete processing systems can be analysed, tested, and evaluated in terms of size, output, operation, number of stages involved, operating temperatures, flow arrangements, etc., so that the most efficient conditions for the production of a successful end product will be ensured before expense is incurred on installing full-scale plant.

The plant layout has been largely designed on a "Meccano" principle, the strategic deployment of



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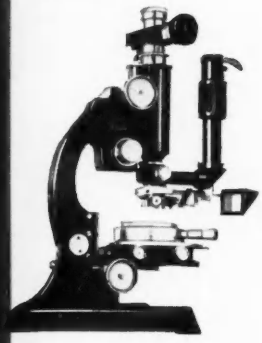

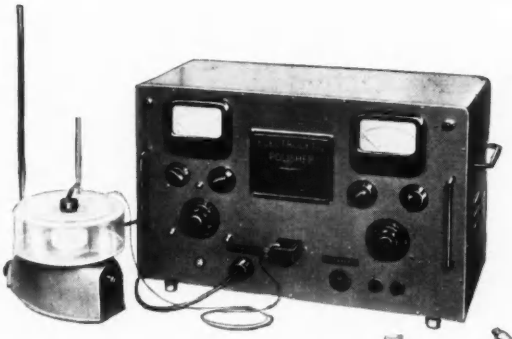

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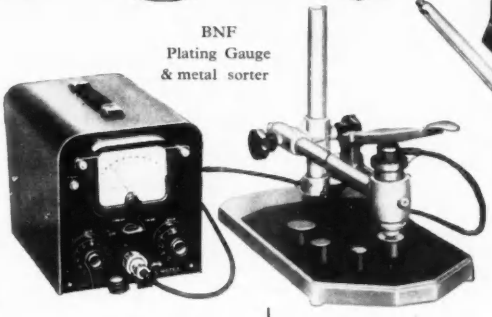

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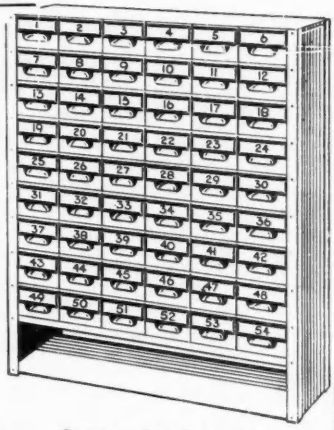

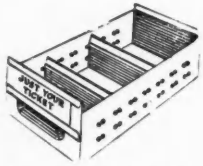

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equipment giving the utmost flexibility to every operation, and the laboratories are so planned that plants can be changed from one process or raw material to another in the shortest possible time, with the help of interchangeable components and ancillaries. This flexibility makes it possible to tackle any problem within the broad framework of chemical engineering, from simple storage to a complete process.

New Aluminium Strip Mill for Birmetals

Installed by Birmetals Limited at Woodgate Works, Quinton, at a cost of £1,000,000, a new strip mill, the first of its kind in Europe devoted to the rolling of aluminium alloys, will be capable of rolling between 12,000 and 20,000 tons of aluminium sheet per year when fully operational. At present, the coil being rolled weighs just over 8000 lb (equivalent to 11 tons in steel), but eventually the mill will be capable of handling a coil of up to 10,000 lb in weight.

The machine itself is a 50-in. reversing mill capable of rolling aluminium alloys in coil form at speeds up to 1600 fpm. The finished width of the coil obtained is 48 in., and the thicknesses which can be obtained have the remarkably wide range of from $\frac{3}{16}$ in. down to as little as 0·006 in. As the strip leaves the mill on the outgoing side, the gauge is indicated by ultrasonic instruments which measure the thickness. The $2\frac{5}{8}$-in. diameter work-rolls are ground to such a precision that the material produced has absolute uniformity across the width—a feature hitherto unknown in the rolling of aluminium alloys. A roll-change in the mill can be effected in less than 30 sec, thus making the mill very flexible in its capabilities.

The welding line, which is composed of a number of ancillary units and a flash butt-welding unit, forms a complete unit to produce the desired heavy coil demanded by the Sendzimir mill. The electrical load on flashing the butt welder is 290 kVA and, at the instant of forging, 2320 kVA.

Course on Measurement for Automatic Control

Providing an introduction to the principles of measurement for automatic control purposes and a survey of industrial applications, a week's residential course on measurement for automatic control will be held at the University of Nottingham between September 12 and 16, 1960. No formal academic qualifications are required for enrolment in this course, but the lectures have been designed for those with a degree or a Higher National Certificate standard of education and attainment. Copies of lecture papers will be circulated in advance to all those who register for the course, with which will be held concurrently an exhibition of equipment provided by leading manufacturers.

As accommodation is limited, those desirous of enrolling for the course should apply as soon as possible to the Organizing Secretary, Measurement of Automatic Control Course, Faculty of Applied Science, The University of Nottingham, University Park, Nottingham.

Classified Advertisements

PUBLIC APPOINTMENT

THE UNIVERSITY OF LEEDS
DEPARTMENT OF MECHANICAL ENGINEERING

The University of Leeds intends to appoint a person to be in charge of the technical staff within the Department of Mechanical Engineering. Applicants should hold a university degree or the qualification A.M.I.Mech.E. The Department will shortly be moving into a new building and will have a greatly increased area of laboratories and workshops, and the person appointed will be in charge of technicians in these. The successful candidate will be directly responsible to the Head of the Department and will receive a salary on the scale £1,050 x £50—£1,400 x £75—£1,850 (efficiency bar probably at £1,550), according to age, qualifications and experience.

Applications (three copies) stating date of birth, qualifications and experience, together with the names of three referees, should reach the Registrar, The University, Leeds, 2 (from whom further particulars may be obtained) not later than August 8, 1960.

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NEW TECHNICAL BOOKS

High Productivity in Heavy Engineering. By A. G. Thompson, B.Sc., A.M.I.C.E., M.I.E.S., A.M.I.W. 347 pp., 222 illustrations. Publishers: Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 65/– (postage 1/3).

Fundamentally concerned with production inspection and cost control in welded fabrication, this authoritative and well-illustrated book mainly deals with the technology which has built up around welded fabrication. As such, it covers such subjects as accurate dimensioning, coding, methods of transferring dimensions, and cutting machines, including computer-controlled flame-profiling machines using punched or magnetic tape, and welding machines. Details are given of the latest metal-working processes essential for efficient fabrication and of the various machines that have been specially evolved for preforming sheet and plate, as well as such matters as shop layout, assembly and handling, and quality control and inspection, including the latest methods of non-destructive testing. In addition, part of the book is devoted to costing methods appropriate to heavy fabrication, covering various aspects of this subject, such as productivity improvement, in which examples taken from heavy engineering illustrate the specialized approach that is essential.

There can be no doubt that this book is of definite practical value to all those responsible for the fabrication of metal by welding, including management, engineers, designers, and production and planning staffs.

Engineering Mathematics. By J. Blakey, Ph.D., and M. Hutton, Ph.D. 606 pp., 142 illustrations. Publishers: Blackie & Son Limited, 17 Stanhope Street, Glasgow, C.4. Price: 40/–.

Based on the well-known and popular text-book "University Mathematics" by Dr. Blakey and, indeed, retaining the bulk of its contents, this new and excellent version has been arranged in a form more suitable for engineering students of degree standard. As such, the more theoretical chapters of "University Mathematics" have been removed and have been replaced by chapters on the numerical solution of equations, statistics, relaxation methods, and Laplace transformations.

Well-written and produced, and including a wealth of illustrative examples with answers, there can be no doubt that this book will amply cover the mathematics needed for a degree in engineering at most universities.

Numerical Methods for High-Speed Computers. By G. N. Lance, M.Sc., Ph.D., M.I.A.S., A.F.R.Ae.S. 174 pp., 6 illustrations. Publishers: Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 42/– (postage 11d.)

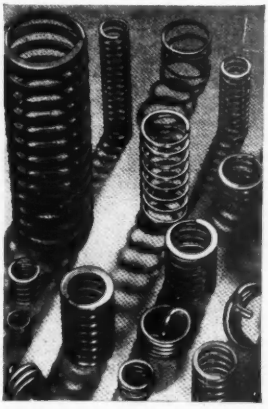
Programmers of electronic computers frequently find that classical methods of mathematical computation do not take full advantage of the facilities provided by modern automatic high-speed computing machines. For this reason, new methods of solving complicated problems have been developed, many of which are applicable only to electronic computers and are not readily available, as they have appeared exclusively in original papers which may have a limited circulation. This interesting book therefore fills a much needed gap in that the author, who is in charge of the Digital Computer Group of the Atomic Energy Establishment in Winfrith, Dorset, has, for the first time, collected into a single volume the most useful of these new methods, including some which he himself has developed.

Presenting a thoroughly practical approach to the subject, this well-written and useful book includes mathematical formulæ and methods which are general in the sense that they are applicable to most modern computers and are therefore of value to all programmers, irrespective of the type of machine available. Important considerations, such as the degree of accuracy, the amount of storage space required, and the time taken to achieve the result, are also given, together with the various methods of evaluating functions, the solution of problems which can be posed in matrix form, as ordinary differential equations or as partial differential equations, and miscellaneous methods of solving equations.

British Plastics Year Book, 1960. 30th Edition. 696 pages. Publishers: Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 42/– (postage 1/9).

Divided into nine sections, conveniently tabbed for ready identification, the *British Plastics Year Book* remains the only classified guide to the products and manufacturers of plastics, making it invaluable to all those connected with the plastics industry and to manufacturers and users of machinery and equipment.

In addition to classified lists of manufacturers and suppliers of materials, finished products, and equipment, the world's largest list is included of trade and proprietary names connected with the industry, covering materials as well as finished goods, each trade name being followed by a definition of the product and the manufacturer concerned. In this new edition, the names-and-addresses section, containing nearly 7000 firms associated with plastics, is now divided into two parts, one for the U.K. and the other for overseas, the latter being considerably enlarged and now listing about 4000 firms. In addition, like all other sections, the set of tables giving the comparative properties of plastics materials has been revised and brought up to date, as also have the glossary of technical terms, the lists of new companies registered, the specifications relating to plastics, and the "Who's Who" section.



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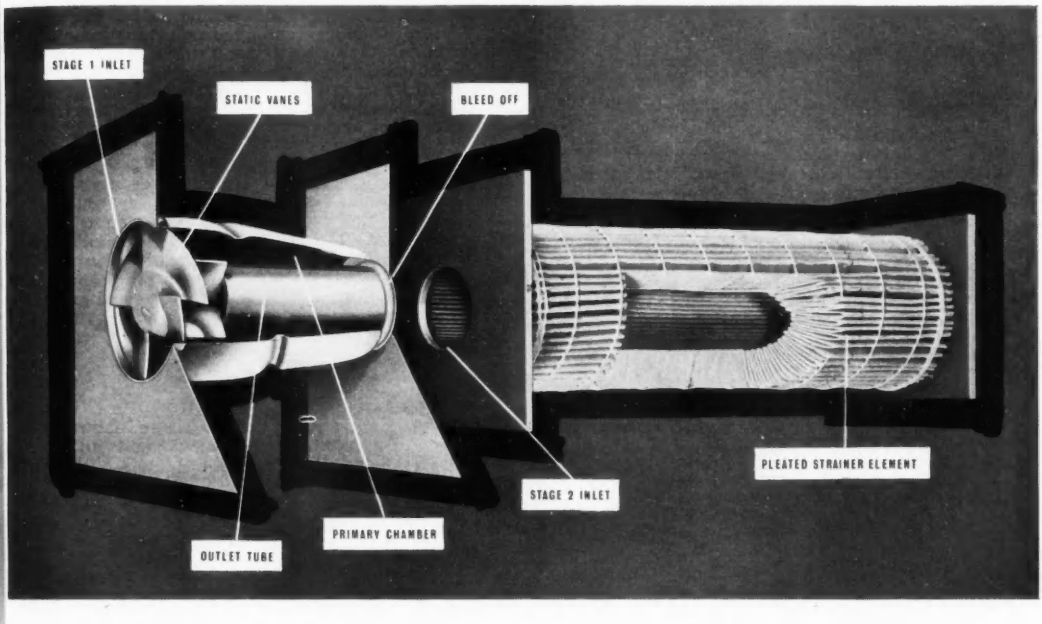

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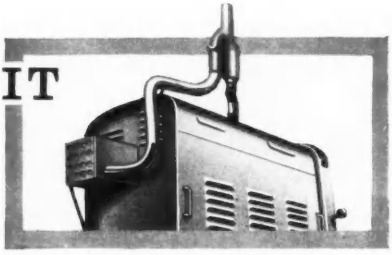

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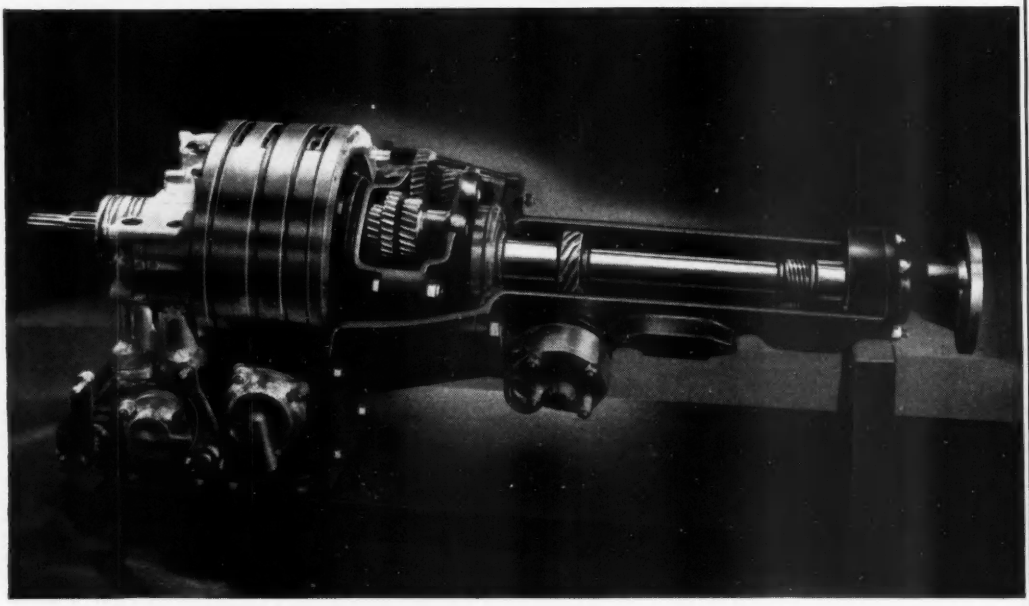

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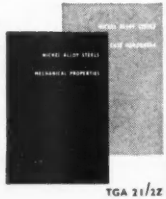

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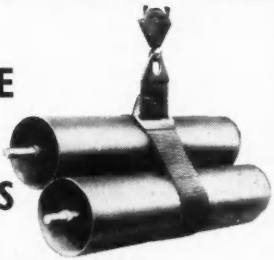

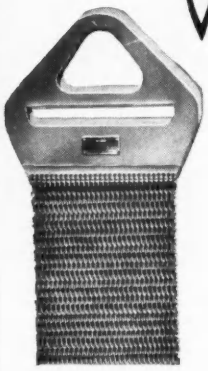

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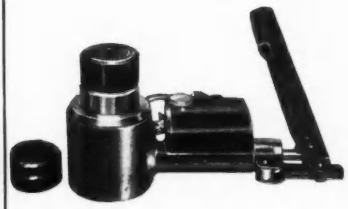

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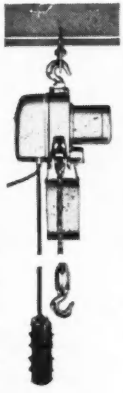

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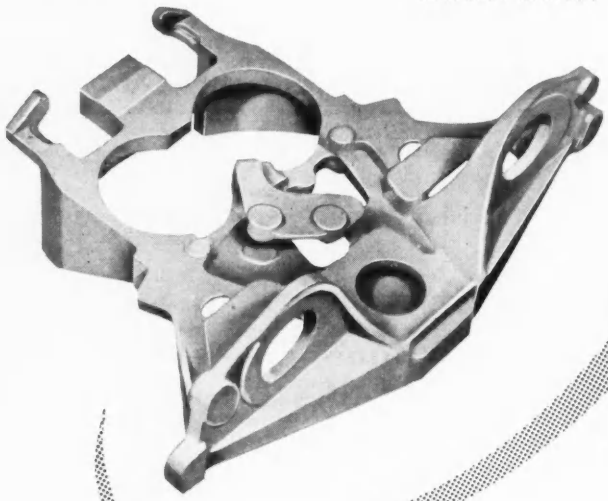

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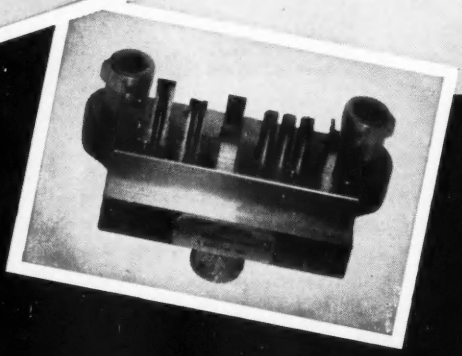

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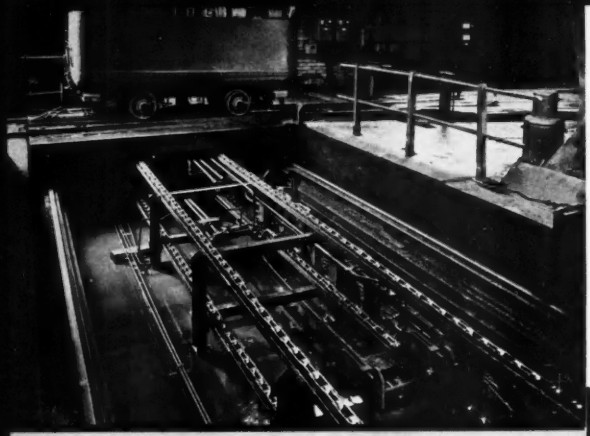

Keelavite in the mines. Among the very many uses made of Keelavite equipment by the rapidly modernising mining industry is this traverser, working round the clock in a South Wales colliery. Hydraulics have brought automation to mining. Hydraulics easily cope with the continuous movement of heavy loads.

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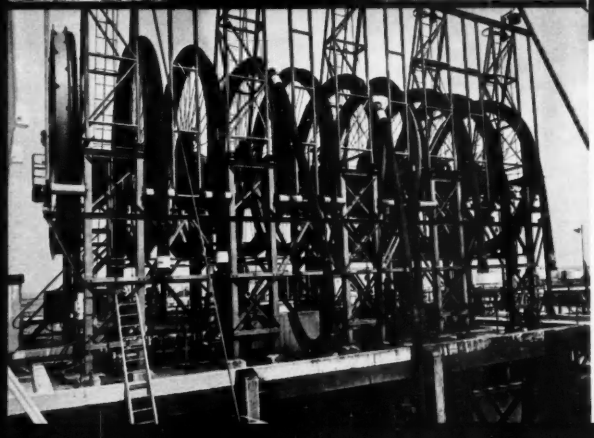

First of its kind in Europe, this ingenious hose-reeling mechanism is operated by Keelavite hydraulics. Built for the Mobil Oil Company at their Coryton Refinery. Each of the 10 reels takes 60 ft. of 8 inch hose. Hoses are used for handling tanker cargoes; up to 800 tons per hour per hose.

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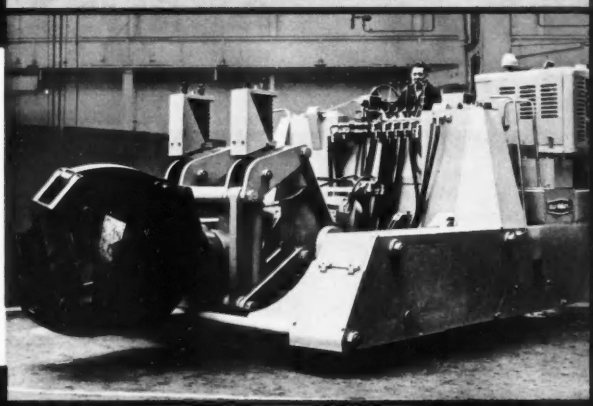

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Exactness in aerodynamic research makes use of Keelavite hydraulics. At the Royal Aeronautical Establishment, Bedford, the side walls of the large supersonic wind tunnel are jacked with the aid of hydraulic motors. For details of these units see overleaf . . . .

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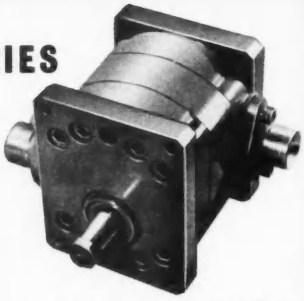
Hydraulics

THE RECOG
HYDRAULIC
present a smal
hydraulic units

GEAR PUMP/ MOTORS

Available in 6 basic sizes from which are manufactured, as standard, 17 pump motors of different ratings. As pumps output ranges from 2·25 g p m to 180 g p m. As motors torque ranges from 52·5 lb. in. to 12,560 lb. in.

G.P. SERIES GEAR PUMPS



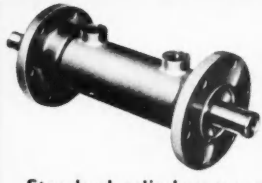
A range of low cost, high performance, plain bearing gear pumps covering displacements from 4 to 33 g p m at 1,000 r p m Pressure—3,000 p s i. Speed—3,000 r p m.

POWER PACKS

Keelavite power packs provide a range of self-contained hydraulic power units.

Name	Tank capacity	Electric motor h p
Midget	7½ gall.	Up to 2
Minor	20 gall.	Up to 5
Major	50 gall.	Up to 12½
Mighty	75 gall.	Up to 25

Power packs are assembled from standard units.

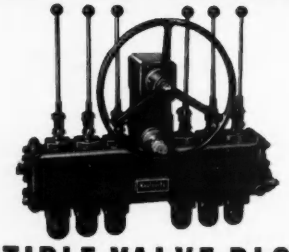


DOUBLE ACTING CYLINDERS

Standard cylinders are available for working pressures up to 2,000 p s i, in the following sizes:

Bore dia.	1″	1½″	2″	2½″	4″	5″	6″	7½″
Max.stroke	6″	40″	40″	70″	80″	100″	130″	144″

Mountings: flange, clevis, and foot are standard. Special cylinders made to order.



MULTIPLE VALVE BLOCKS

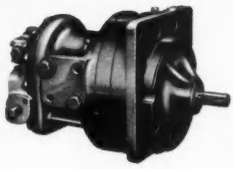
Combinations of two or more 'slices', together with the appropriate end pieces, provide centralised control of many kinds of manually operated hydraulic systems. A steering valve can be incorporated.

'FEEL VALVE'

For heavy duty brake and clutch operation. The operator is able to sense hydraulic pressure: the more the pressure the greater the resistance. Usually sold in pairs, as illustrated.

COGNISED AUTHORITY ON LIC POWER TRANSMISSION

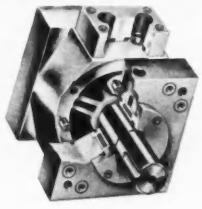
small selection from their range of nits . . . they have a unit for every use



ROTARY ABUTMENT UNITS

Long life, as wear cannot take place between the pumping elements, no surfaces being in contact. For use as pumps or motors.

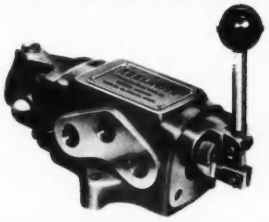
Type	Max. pressure	Max. output gpm at 1430 rpm	Max. h p at 1430 rpm
202	750	10·3	5·4
502	1500	25·7	26·9
1502	1500	77·4	81·0
V548 (variable) capacity type	750	28·2	19·6



ROTARY TORQUE ACTUATORS (ROTAC)

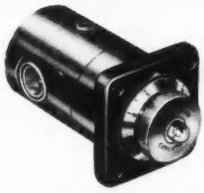
A simple device for producing reciprocating rotary power. Effective internal sealing gives accurate control. Available as follows:

	Torque range in/lb at 100—1000 p s i	Rotation	Displacement cu/in.	
RN- 32-1V	100- 1500	280°	9·2	1000 p s i
RN- 32-2V	240- 3200	100°	6·6	
RN- 63-1V	650- 8700	280°	53·3	
RN- 63-2V	1800-19000	100°	38	
RN-105-1V	3200-40000	280°	255·3	
RN-105-2V	8800-92000	100°	181	



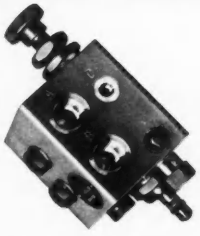
DIRECTIONAL VALVES

For pressures up to 3,000 p s i and pipe sizes from ¼" to 2" B S P. Various methods of control are available, including handlever, stem operation, solenoid operation, servo operation.



SPEED CONTROL VALVES

For regulating the operating speed of hydraulic actuators. Available with port sizes from ⅜" to 1½" B S P with maximum flow ranges from ½ g p m to 60 g p m. Viscosity compensated. Hand wheel, dial, or servo control.



FLOW CONTROL VALVES

These valves permit a controlled flow of oil as set by a speed control valve, and maintain this flow irrespective of load variations. Available in port sizes from ½" to 1½" B S P.

See also relief by-pass and flow control valves.

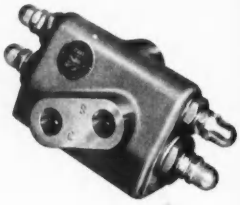
NON-RETURN VALVES

These valves permit the flow of oil in one direction only. Available with ¼" to 2" B S P port sizes with back pressures to suit application. Maximum working pressure 2,240 p s i. Can be used as a low pressure relief valve, with a suitable spring.

RELIEF, BY-PASS & FLOW CONTROL VALVES

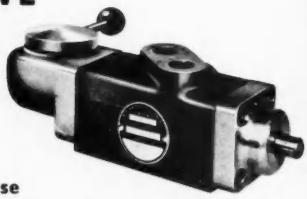
A single, basic, design incorporates these functions. Available with port sizes from ½" to 2" B S P suitable for direct or pilot operation. Wide range of control pressure settings.

FLOW BALANCING VALVES

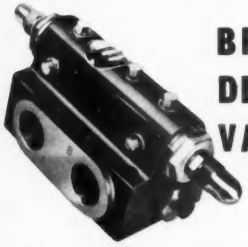


Used to split an oil flow to move two hydraulic actuators at the same speed, irrespective of load. Available with port sizes from ⅜" to 1½" B S P.

SENSITIVE VALVES



Designed for use as the control valve in hydraulic copying devices for machine tools. The Keelavite range includes units for manually and servo operated fast approach and return.



BRAKING & DECELERATING VALVES

These valves prevent shock loads due to the inertia of the machine being operated. Available with port sizes from ¼" to 2" B S P. Pressures from 0—1,600 p s i and 1,200 to 2,500 p s i.

MICRO-FILTERS

Essential in hydraulic installations designed for accurate operation.

Available with either 5—10 micron or 15—20 micron filtration. A by-pass valve and a warning device can be incorporated to operate in the event of filter blockage. Maximum pressure 3,000 p s i.

INSTALLATION SERVICE

There is more to an hydraulic system than the mere piping up of units. Keelavite installation engineers are trained specialists whose experience in industrial hydraulics will save you both time and money.

KEELAVITE HYDR

Allesley · Coventry · Warwick

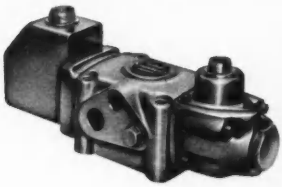
FOR ADVICE ON ANY HYDRAULIC PRO

REDUCING VALVES

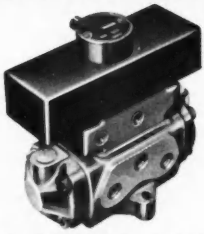
Available with port sizes from ⅜" to 2" B S P.

These valves are used where a reduced operating pressure is required in part of an hydraulic circuit.

ELECTRO-HYDRAULIC SERVO VALVES



For very accurate control of hydraulic actuators by means of an electronic system. Available in two sizes with a pressure drop of 1,000 p s i at 25—30 g p m and 100 g p m.



SOLENOID VALVES

For electrical control of large directional valves, pilot operation by means of a solenoid operated valve is often desirable. Solenoids are available for A C or D C operation; with a maximum working pressure of 2,000 p s i.

PILOT OPERATED NON-RETURN VALVES

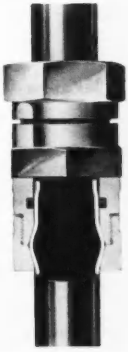
Free oil flow in either direction is possible until pilot pressure is applied. The unit then acts as a non-return valve. Available with port sizes from ⅜" to 1¼" B S P.

DESIGN SERVICE

Thousands of Keelavite designed hydraulic systems are giving successful service at this moment. Wide experience enables Keelavite engineers to offer you a really helpful circuitry service.

PIPE COUPLINGS

Keelavite patented pipe couplings are designed to fulfil the requirements of high standard hydraulic installation work. They will withstand high pressures and vibration. Machining and heat are unnecessary. Infinitely re-usable.



RAULICS LIMITED

vickshire • *Telephone:* MERIDEN 441

PROBLEM—ASK FOR 'COMMERCIAL SALES'

HERE ARE THE ANSWERS TO A FEW HYDRAULIC PROBLEMS—

ASK KEELAVITE ABOUT THE OTHERS

Imp. Gallons × 277·4 = cu. in.

Cubic inches × 0·0036 = Imp. gallons.

Cubic inches × 16·39 = cubic centimetres.

Cubic centimetres × 0·0610 = cubic inches.

U S gallons × 0·8327 = Imperial gallons.

Imperial gallons × 1·201 = U S gallons.

Cubic inches × 0·0043 = U S gallons.

Imperial gallons × 0·1605 = cubic feet.

Cubic feet × 6·229 = Imperial gallons.

Litres × 0·22 = Imperial gallons.

Feet × 30·48 = centimetres.

Centimetres × 0·0328 = Feet.

H P × 1·014 = C V (French H P).

C V × 0·9863 = H P.

U S Gallons × 3·785 = Litres.

Litres × 0·2642 = U S gallons.

$\left(\frac{9 \times °\text{Centigrade}}{5}\right) + 32 =$ Degrees Fahrenheit.

$\frac{5 \times (°\text{Fahrenheit} - 32)}{9} =$ Degrees Centigrade.

Pressure lb./sq. in. × 0·06804 = atmospheres.

Pressure lb./sq. in. × 0·07031 = Kg./sq. cm.

Flow: gallons/min × 4·543 = litres/min

Pump flow (g p m) =

$$\frac{\text{Displacement (cu. in. per rev.)} \times \text{Speed (r p m)}}{277 \cdot 4}$$

H P output of hydraulic pump =

$$\frac{\text{Flow (g p m)} \times \text{Pressure (p s i)}}{1430}$$

H P output of hydraulic motor =

$$\frac{\text{Torque (lb. in.)} \times \text{Speed (r p m)}}{63063}$$

Torque developed by hydraulic motor (lb. in.) =

$$\frac{\text{Capacity (cu. in. per rev.)} \times \text{Pressure (p s i)}}{2 \times 3 \cdot 1416}$$

Cylinder thrust (lb.) =

Pressure (p s i) × Piston area (sq. in.)

Pump output for cylinder frequency =

$$\frac{(\text{Piston area} + \text{annular area}) \times \text{Stroke} \times \text{required frequency}}{277 \cdot 4}$$

USEFUL VALUES

1 cu. ft. of water weighs 62·4 lb.
1 gallon of water weighs 10 lb.
*1 cu. ft. of oil weighs 53·6 lb.
*1 gallon of oil weighs 8·55 lb.
1 foot head of water = 0·43 p s i
*1 foot head of oil = 0·37 p s i
*Specific gravity = 0·86

*Approximate values for medium hydraulic mineral oils.

KEELAVITE Hydraulics

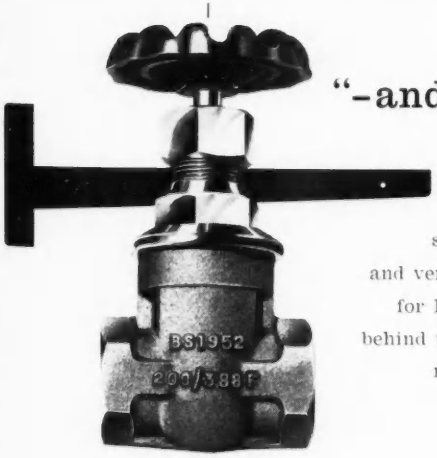
KEELAVITE HYDRAULICS LIMITED
ALLESLEY · COVENTRY · *Telephone: Meriden 441*

Printed in England

JAMES

JULY

E.D.

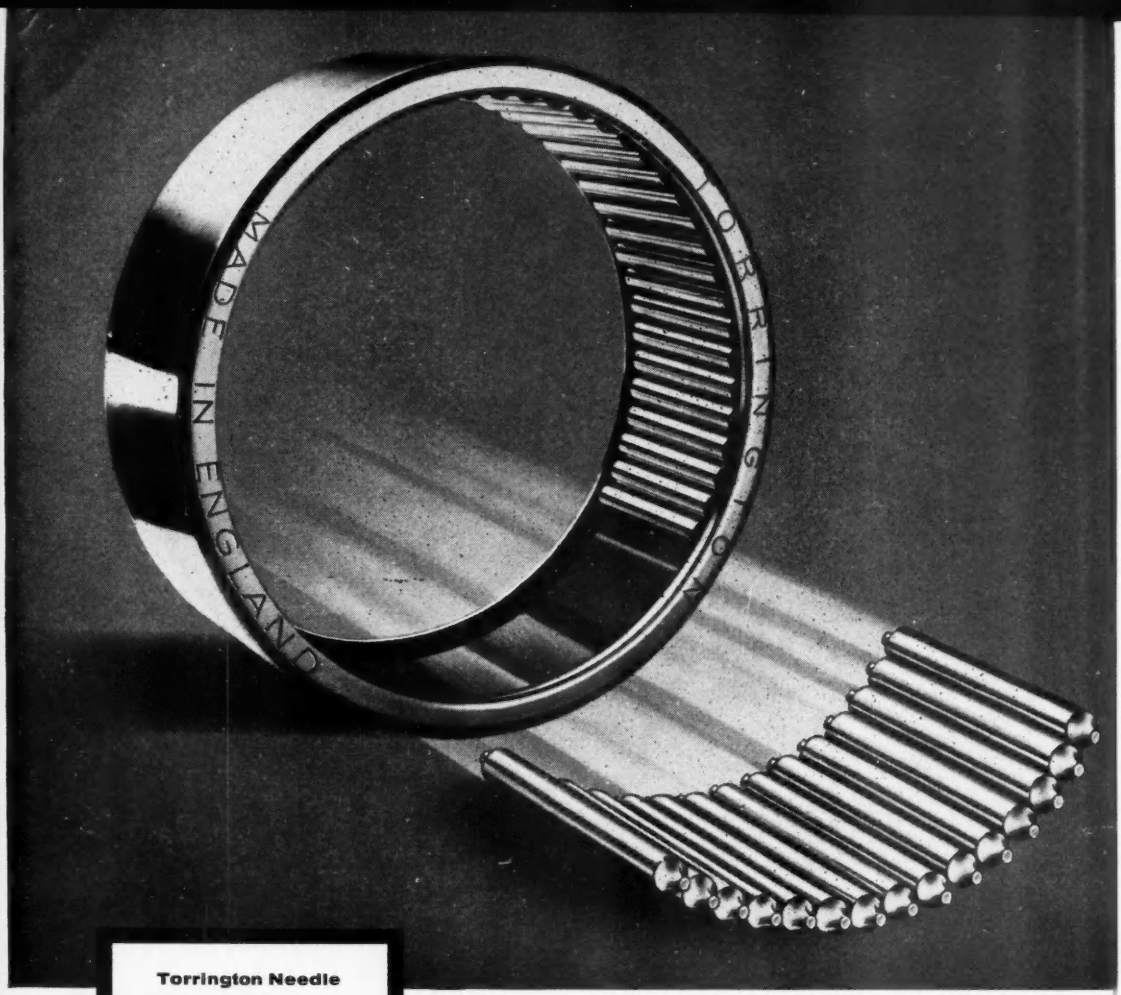


"-and specify BARWELL valves!"

These BARWELL people make a fine range of valves applicable to steam, water and oil services. Their products are of excellent design and very well made. Mark you, that's understandable, for BARWELLS have nearly two centuries of experience behind them — and experience counts. They are that rarity — traditional craftsmen with contemporary minds.

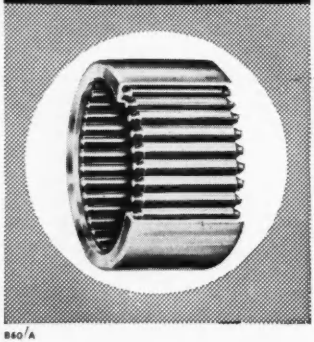
BARWELL

JAMES BARWELL LTD., GT. HAMPTON ST., BIRMINGHAM 18. Tel: NOR 1307 pbx. Grams: Barbells, B'ham.



Torrington Needle Bearings feature:

- *high radial load capacity*
- *low coefficient of starting and running friction*
- *low unit cost*
- *long service life*



B60/A

This is why Torrington Needle Bearing provide maximum radial load capacit

The Torrington Needle Bearing's full complement of sm diameter rollers provides the largest possible number of beari contact lines in the load zone. This gives Needle Bearings a high radial load capacity than any other bearing of comparable size.

Precision rollers ensure smooth anti-friction performance wi low coefficient of starting and running friction to match this u equalled capacity. Rollers are positively retained by the turned- lips of the outer shell, permitting simple, economical installati and assembly.

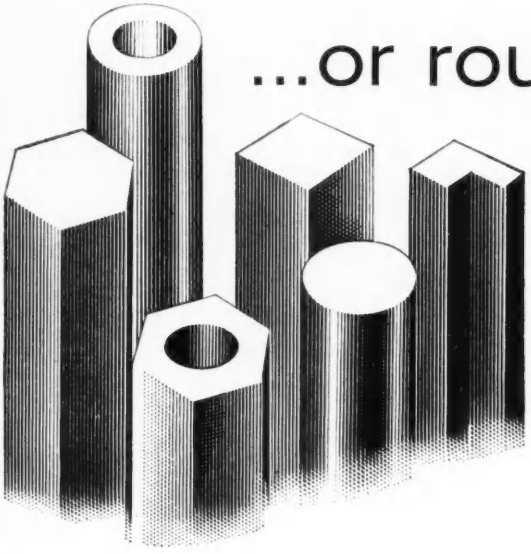
TORRINGTON BEARINGS

The Torrington Company Ltd., Bearings Division, Torrington Avenue, Coventry
London & Export Office: 7-10 Eldon Street, E.C.2

Glasgow Office:
50 Wellington Stree

Clever stuff?

...or routine job?



BOTH at Vickers.
All types of extrusions
in brass. Fine limits,
good quality, quick delivery.

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Non-Ferrous Metals Department
(Division 1),
Vickers-Armstrongs (Engineers)
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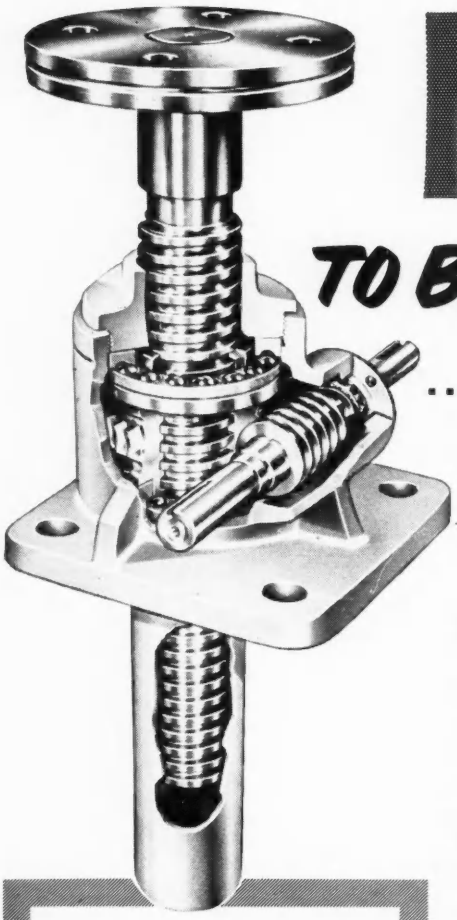
Elswick Works,
Newcastle upon Tyne.
Telephone: 33101

Brass extrusions by VICKERS

Vickers-Armstrongs (Engineers) Limited

TGA 8938A/1



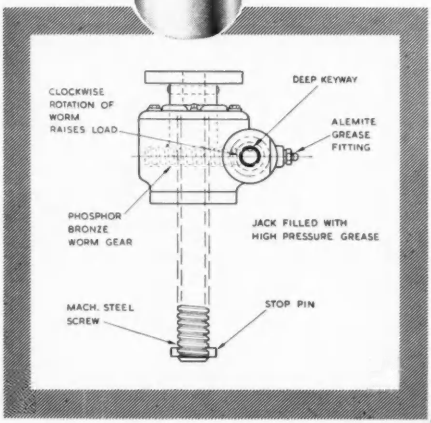
NEW

TO BRITISH INDUSTRY

...a device which every machinery designer should know about

Duff-Norton worm gear jacks provide a purely mechanical means for accurate positioning of loads weighing as much as several hundred tons and maintaining them indefinitely without creep. Operating in any position, and functioning as components of machinery and equipment, they can raise and lower loads, apply pressure or resist impact. Jack capacities range from 5 to 100 tons. When two or more jacks are connected by means of shafting and mitre gear boxes they lift in unison, even when the load is unevenly distributed. They are available with standard raises up to 25 inches, and will provide exactly the same raise for years without adjustment. Worm gear jacks are suitable for operation at ambient temperatures up to 200° F.

Thousands of these jacks are in use in America on feeding tables, tube mills, welding positioners, pipe cut-off and threading machines, testing equipment, aircraft jigs, loading platforms, rolling mills conveyor lines, arbor presses and numerous other types of equipment. If you have a positioning problem, write for catalogue giving complete information, drawings and full specifications.



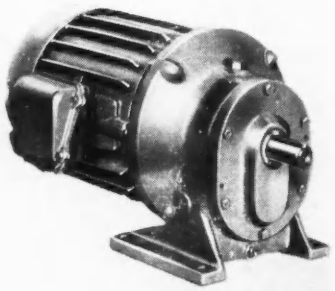
Duff-Norton

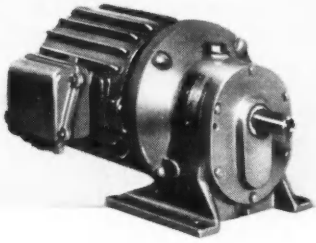
WORM GEAR Jacks

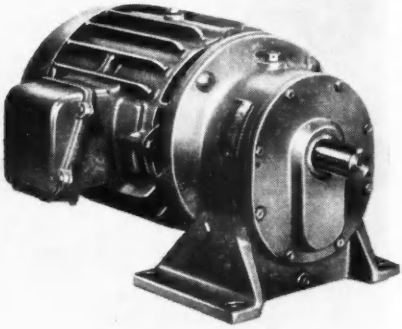
AVAILABLE FROM **Consolidated Pneumatic**

CONSOLIDATED PNEUMATIC TOOL CO. LIMITED · DAWES ROAD · LONDON · S.W.

Low-cost
geared motor units
for industrial service







Type RSD geared motor units have been developed for the many industrial applications where normal standards of silence and efficiency are entirely adequate, and where the use of ultra high-precision gears is not justified.

Three sizes of standard gearbox are offered in a wide range of standard ratios at ratings varying from 1 h.p. at 92 r.p.m. to 7.5 h.p. at 290 r.p.m. All units are equipped with British Standard Dimension motors in either enclosed or ventilated form.

For more arduous duties, and where the highest degree of precision and efficiency is required, AEI recommend the well-established Type RGD units, available up to 40 h.p. output and at ratios up to 23.21 : 1

AEI

Associated Electrical Industries Limited

Motor and Control Gear Division

RUGBY AND MANCHESTER , ENGLAND

INCORPORATING THE MOTOR AND CONTROL GEAR INTERESTS OF BTH AND M-V

AS400

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KERAUNOS High Speed Steel Hacksaw Blades offer exceptional wear-resistance in cutting hard and tough materials such as Nickel-Chrome Steels, Stainless Steels, Tool and Gauge Steels

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Hacksaw Blades.

Write for your copy of our new helpful booklet "What you should know about Hacksaw Blades" and see how you can effectively improve production and reduce machining costs by using KERAUNOS High Speed and PAX Low Tungsten Hacksaw Blades

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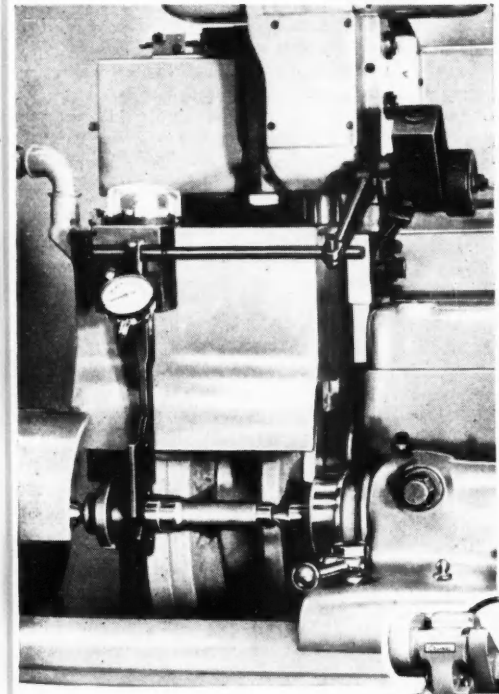
SIZING OF WORKPIECE

TRUING OF GRINDING WHEEL

COMPENSATION FOR WHEEL TRUING

CYCLE CONTROL FOR NUMBER OF WORKPIECES



on

Model 'BW' Plain Grinding Machine

THE CHURCHILL MACHINE TOOL Co Ltd
Broadheath, nr. Manchester.
Altrincham 3262

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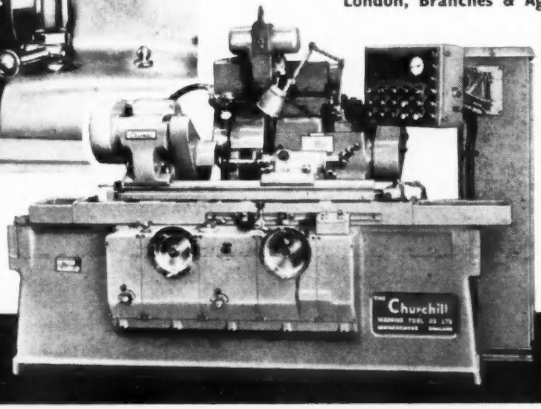

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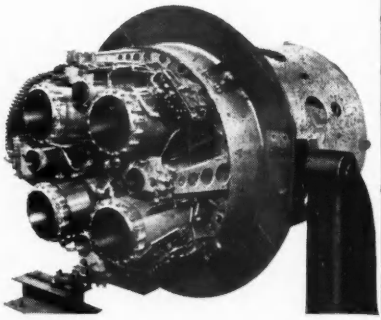
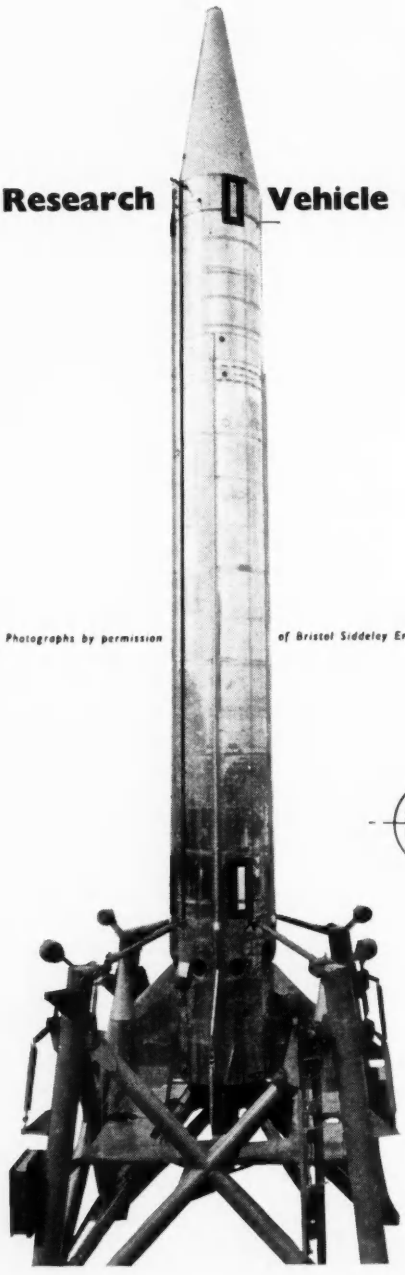


Research Vehicle engines use the Belleville Washer

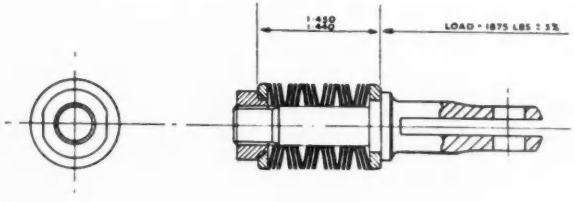


Photographs by permission of Bristol Siddeley Engines

When the Black Knight Rocket roars 150 miles up into space it is guided by the swivelling through an angle of the four combustion chambers of the Gamma engine. An efficient damping mechanism is needed to prevent damage when the limit stop is reached.

Belleville washers provide the perfect answer to the problem.

Belleville washers are solving design difficulties in every industry – where resistance to exceptionally heavy loads is beyond the capacity of helical springs and particularly where movement under shock or sustained load must be restricted to very fine limits. Salter technicians can help you. Their services are freely at your disposal.



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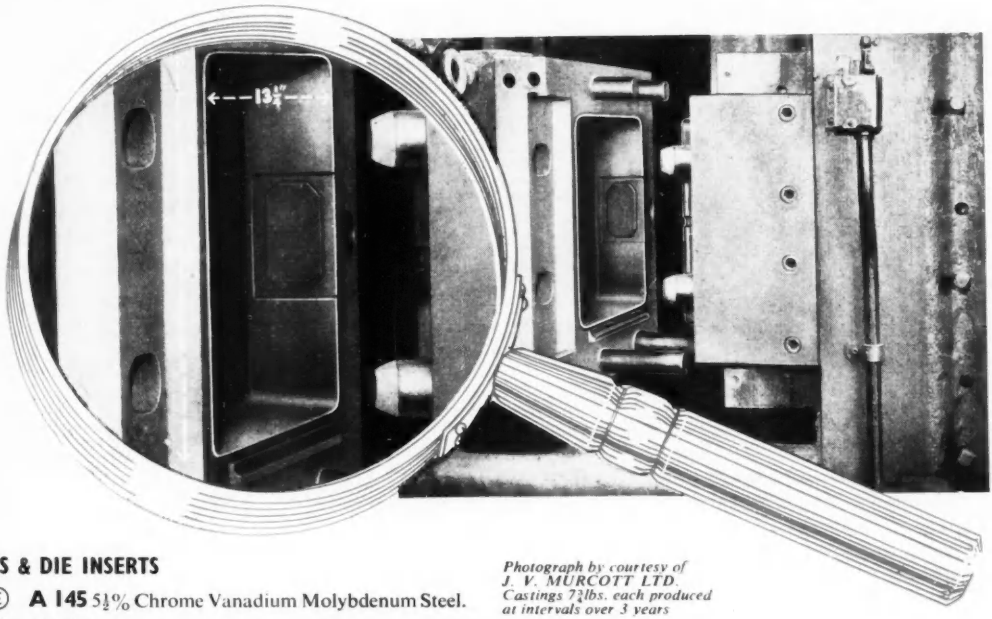

Photograph by courtesy of J. V. MURCOTT LTD. Castings 7¾lbs. each produced at intervals over 3 years

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(KE) **X 369** 5½% Chrome Tungsten Molybdenum Steel.

(KE) **896** Medium Carbon Chrome Vanadium Steel.

Supplied in ultrasonically tested forged blocks and black bars of square, round and rectangular sections.

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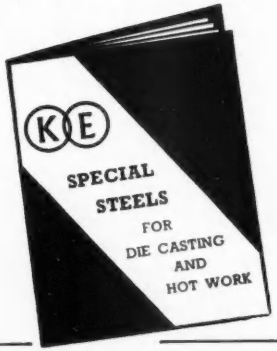
This booklet, giving greater detail, is available free on request.



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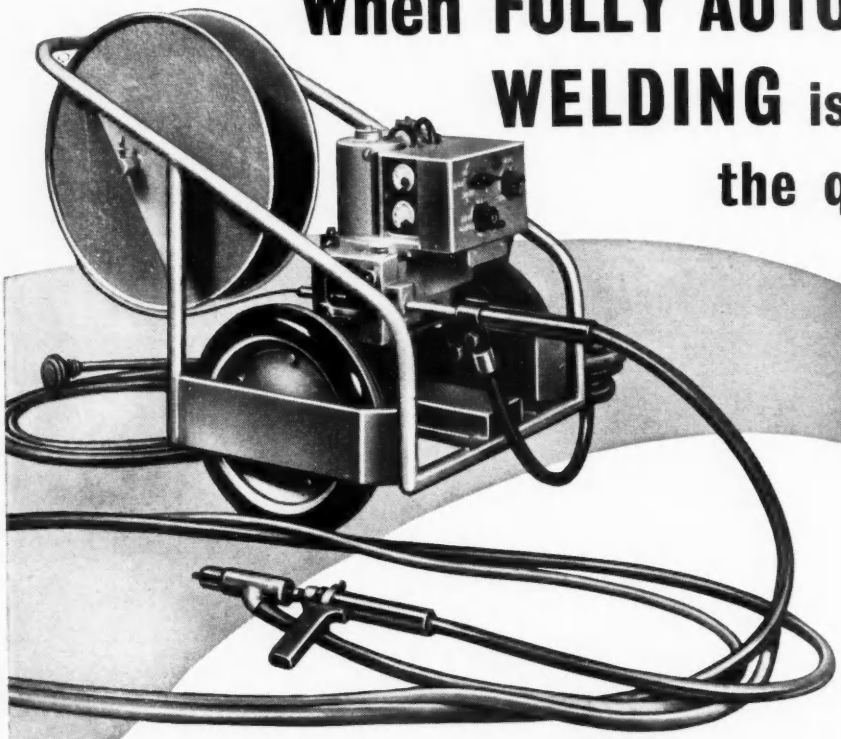

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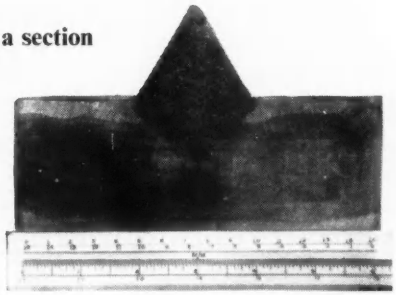
ELECTRO-SLAG WELDING—NEW APPLICATIONS

THINKING AT THE DESIGN STAGE

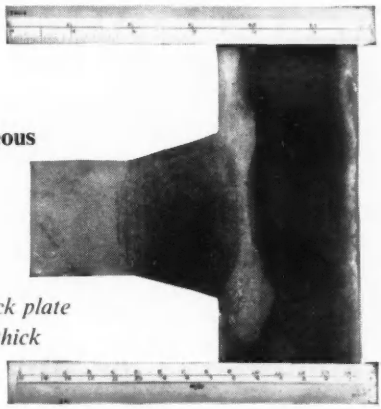
A new process frequently offers unique opportunities for improvement in quality, for lowering of production costs or even scope for truly original application. Re-assessment of problems in design may be possible. To promote new thinking at the design stage two new applications for electro-slag welding by the Rockweld-Vus Vertomatic machine are described.

Adding a section



(*Above*) *One of many shapes of section which can be added to a plate or existing section*

A homogeneous T-weld



(*At right*)
Two-inch thick plate Teed to 2⅜″ thick plate

This particular section was obtained with a single water cooled shoe on a flat surface. It could equally well be applied to a cylindrical surface. The shape is only typical of many which could be adopted and quite a wide range of low alloy steels can be imposed on dissimilar steel plates or forgings. The considerable depth of penetration in this example will be noted but penetration can be varied to suit particular requirements.

ADVANTAGES OF THE ELECTRO-SLAG PROCESS

Vertical Welds in heavy material, impossible by conventional methods.
Unlimited thickness can be welded.
Manipulation of work into position suitable for conventional welding, difficult and expensive with unwieldy heavy sections, is avoided.
Elaborate plate preparation is eliminated.
All welding is done in a single pass—the deslagging and chipping unavoidable with multi-pass welding is eliminated.
Comparative little flux powder is needed and there is no need for continuous flux recovery.
High thermal efficiency allows outstanding economy in welding power consumption.
Can replace heavy forging and casting of heavy parts.
Plate need not be accurately aligned.
The process is fully automatic.
Very high rate of deposition—up to 40 to 50 lb. per hour.
★ ***Production time can be rated in hours instead of days, with less welding labour.***

T-welds in heavy plates or forgings often present problems in design and construction. Homogeneity and shaping of such welds may be difficult in execution by conventional welding methods. Electro-slag welding overcomes such difficulties, provides 100% radiographic results and mechanical properties superior to plate material for most constructional steels. No plate preparation is necessary for this weld.

WELDING DATA

Welding data provided on this experimental section is not necessarily the optimum which could be derived from further tests:

Welding current	600/650 amps.
Welding voltage	36/38 V
Vertical speed of welding...	48″ per minute
Wire consumed	0.5 lb. per inch of weld
Plate thickness	2¼″

WELDING DATA

This weld was carried out with a single wire of ⅛″ diameter. A fixed water cooled shoe was placed on one side of the preparation and a special movable shoe on the other side, using a standard Vertomatic machine.

Welding current	525/550 amps.
Welding voltage	45/46 V
Vertical speed of welding...	31.5″ per hour

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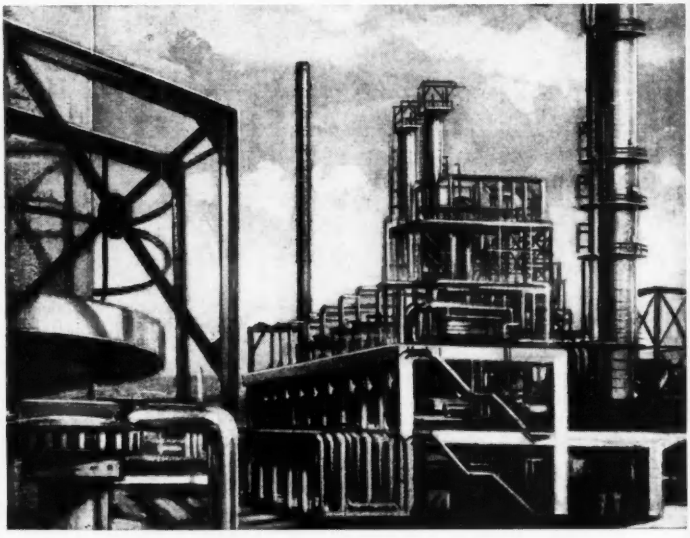

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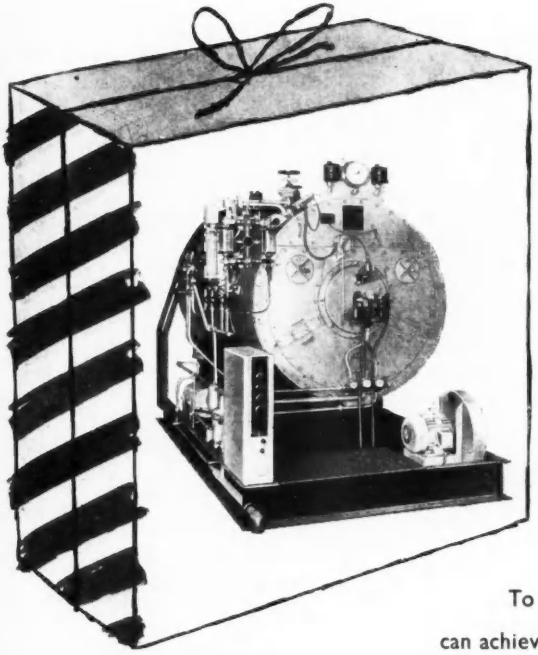

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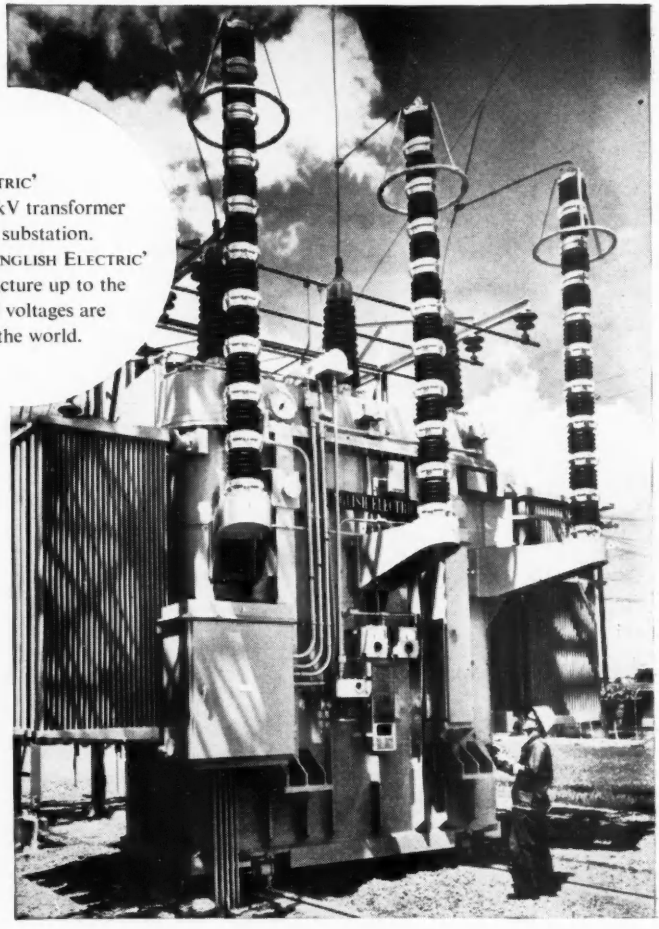

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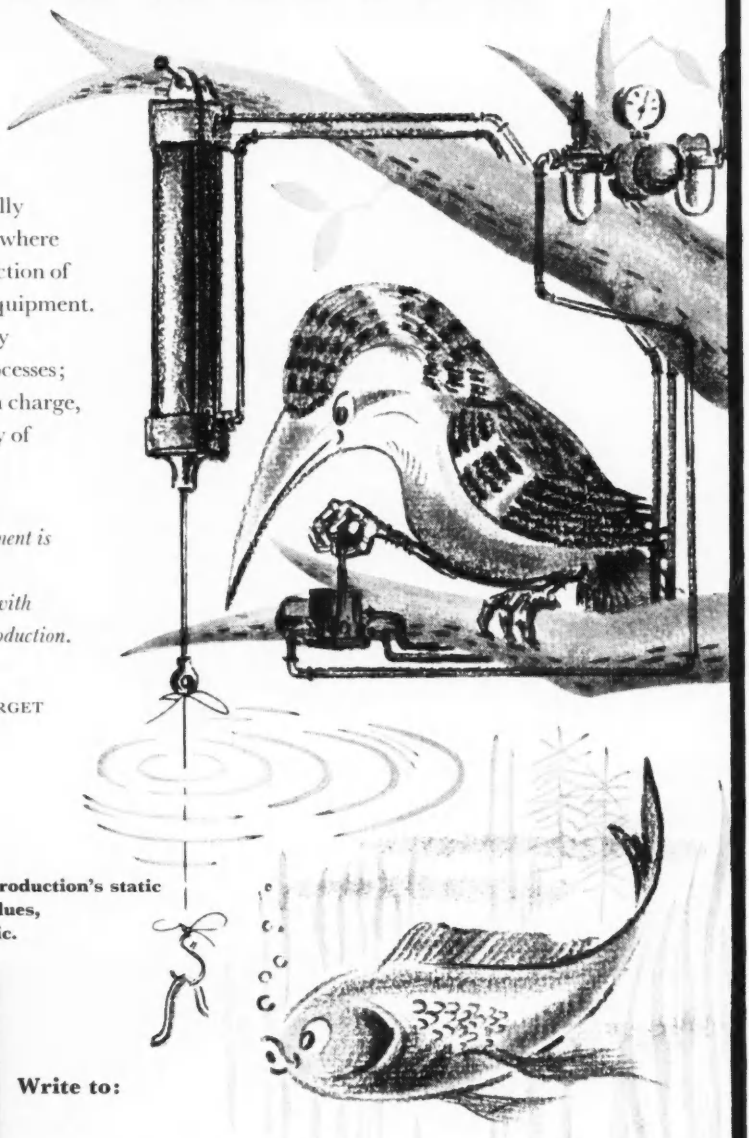
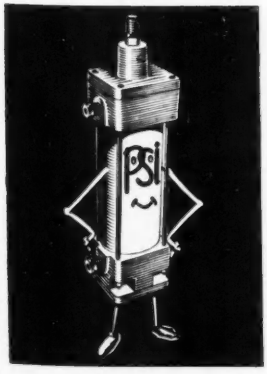


Says Mr. Squinch:
If work is slow—and your production's static
No need to fish around for clues,
Just write to Lang Pneumatic.



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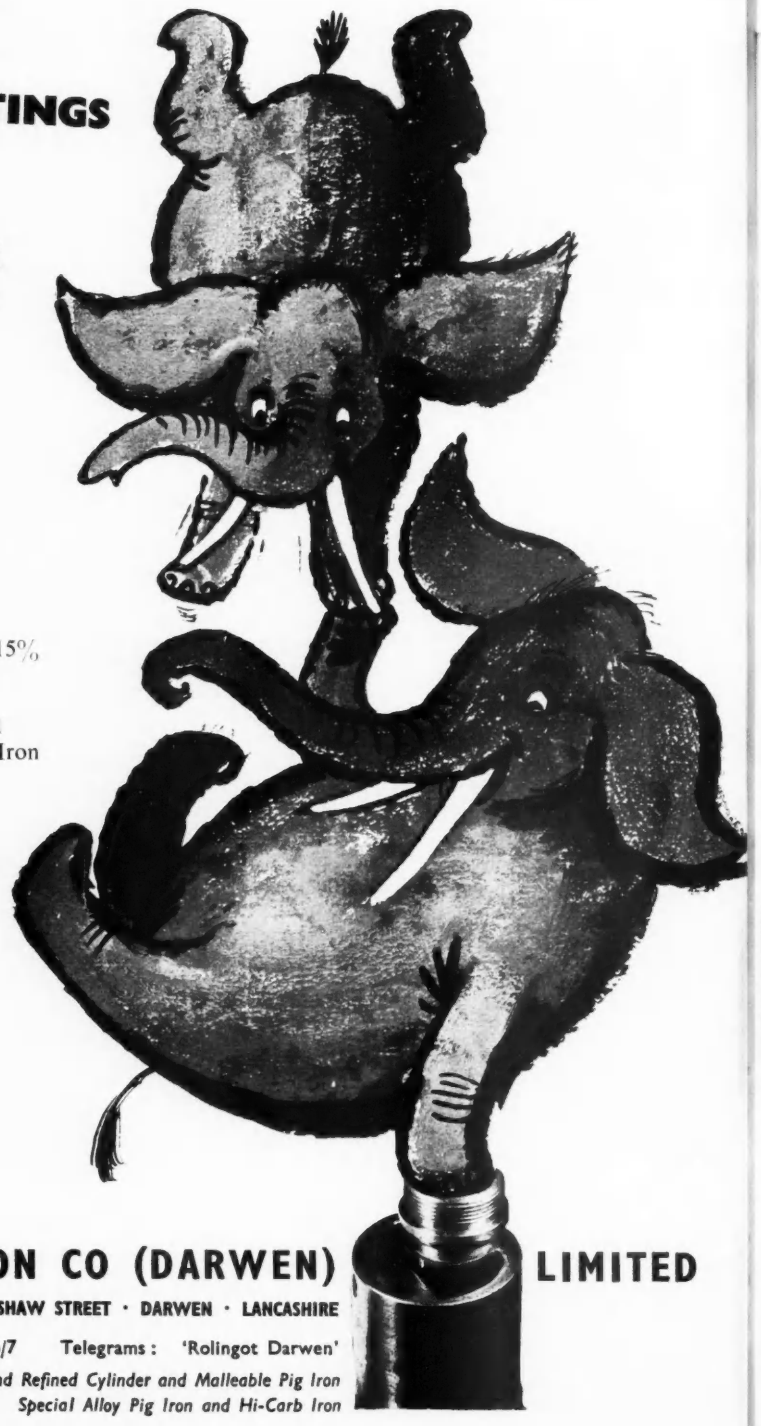

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This refinement also increases tool life and gives Automat (Regd.) Iron its high degree of machining finish.

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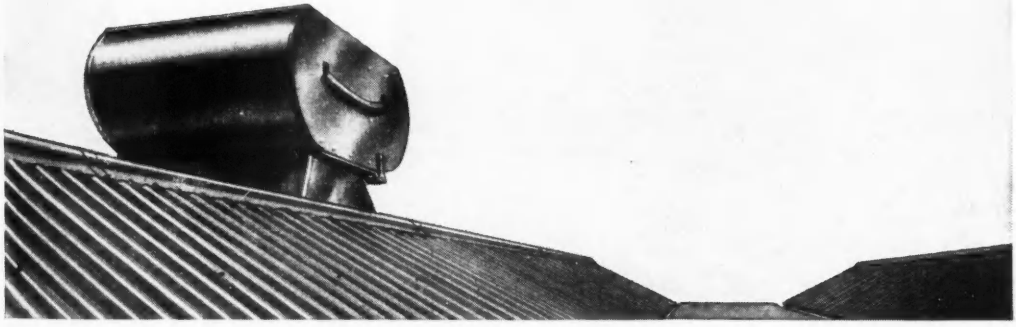

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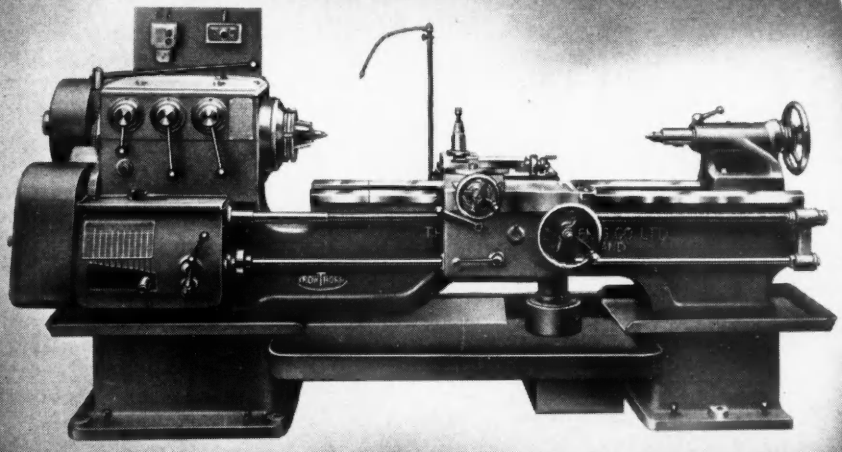
CROWTHORN 7½" CENTRE (15" SWING) GAP BED LATHE



This Crowthorn 7½" Centre (15" Swing) Gap Bed Lathe admits 4' 6" between centres.
Special features include:

L1 long taper spindle nose (alternative A1 short taper)

American style toolpost (Alternative four way toolpost)

Profile ground gears.

Gamet micron precision bearings.

Two-speed motor drive.

A spindle speed range of 19½ to 1,004 r.p.m.

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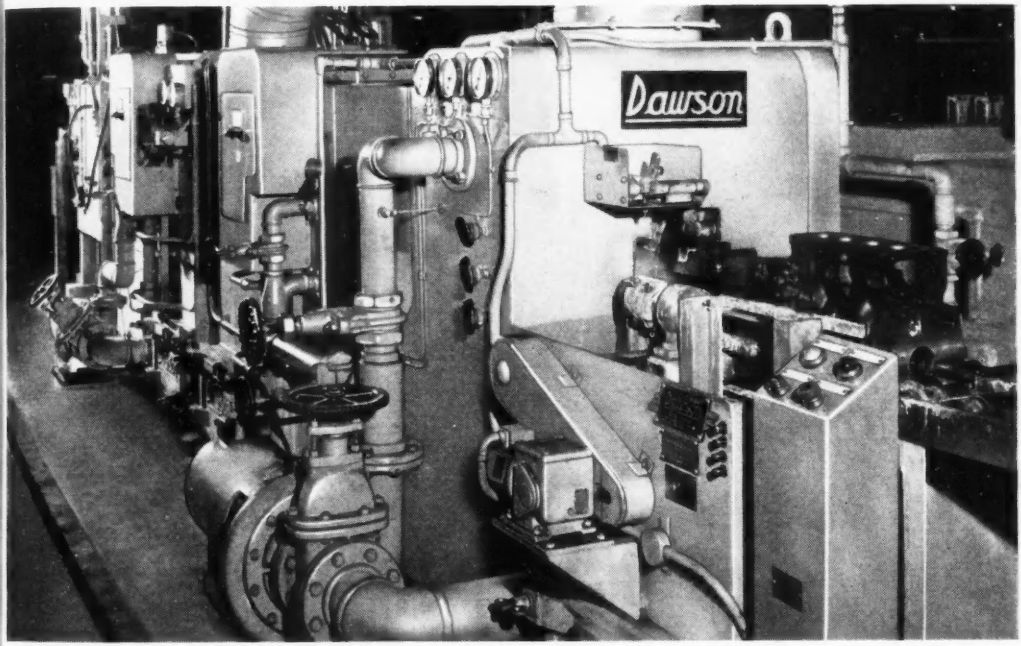
Dawson Automatic cylinder block Washer for the new AUSTIN se7en



The fully automatic Dawson machine illustrated is used to remove all cast-iron swarf and cutting oils from the Austin Seven cylinder blocks before engine assembly. It is continuous in operation and handles up to 80 blocks per hour. The blocks are carried through the machine intermittently pausing at each cleaning station in accordance with a controlled time cycle. An important feature of the machine are the swing type hydraulically operated jetting boxes (patent applied for) incorporated in the washing sections. Each of these has a main nozzle which is spring pressed on the main oil bore gallery at each end of the cylinder block, making a liquid tight connection. Thus the gallery is positively flushed from both ends, the liquid passing through all subsidiary ducts before escaping from the block. In addition, these jet boxes have secondary nozzles accurately registered with all the bores and recesses at the ends of the cylinder blocks.

This high precision cleaning plant is only one of the many Dawson machines installed in the Austin Seven production line.

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Testing a 40" Hypoid Gear and Pinion for a Pulper. *photo by courtesy of Black Clawson International Ltd.*

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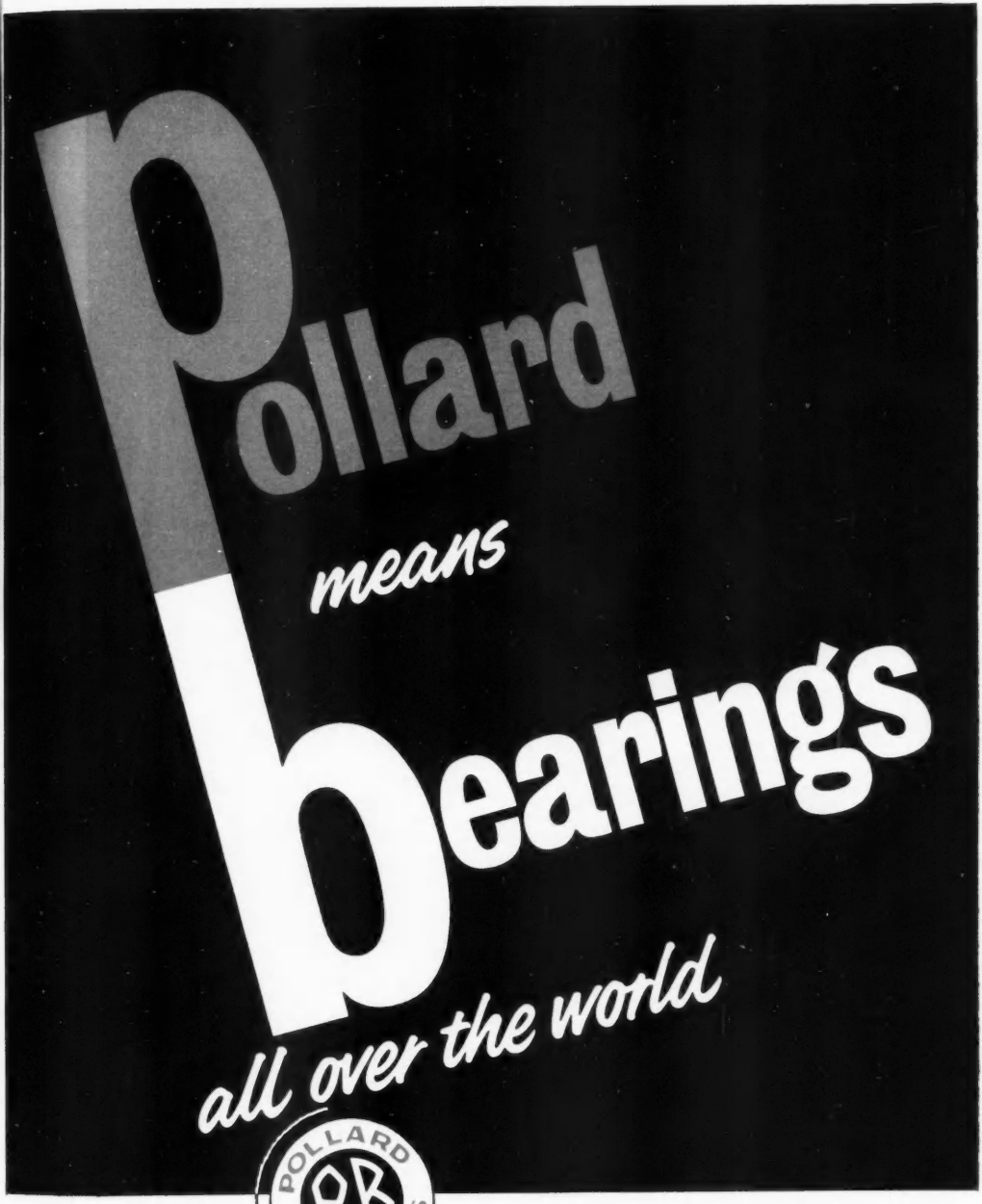

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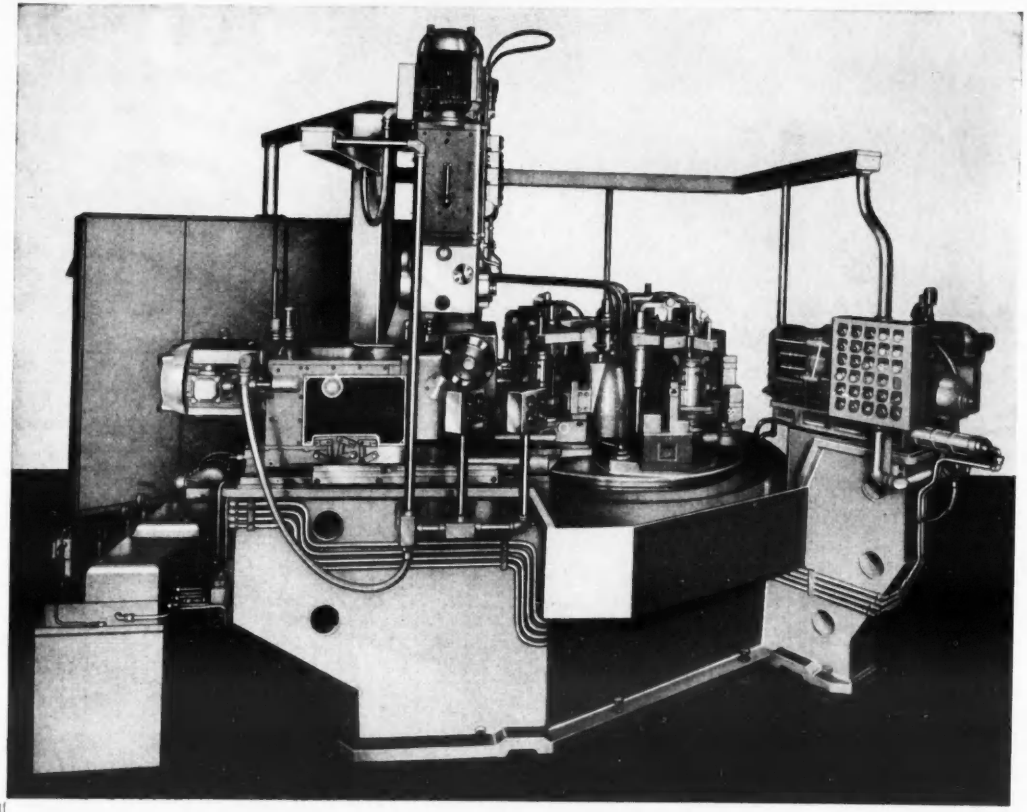

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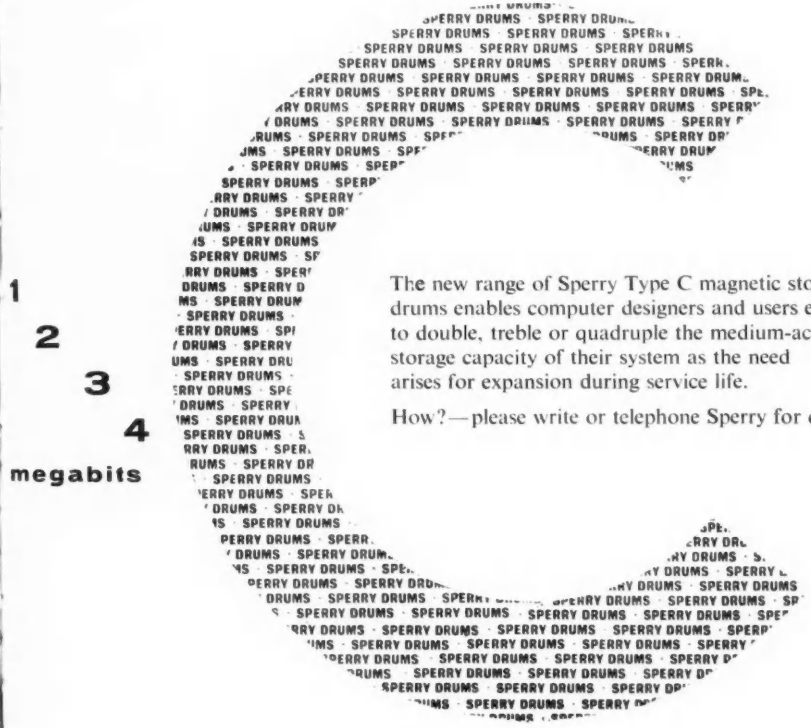

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*.....*Simply the inability to add.*

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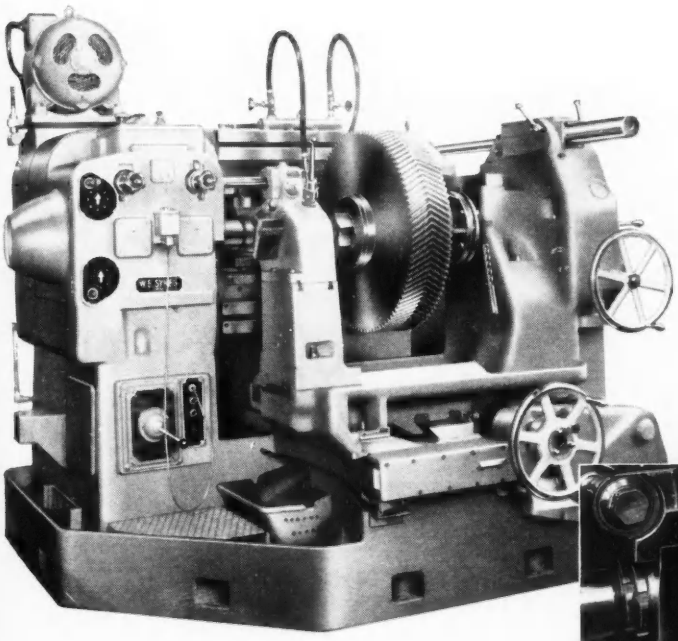

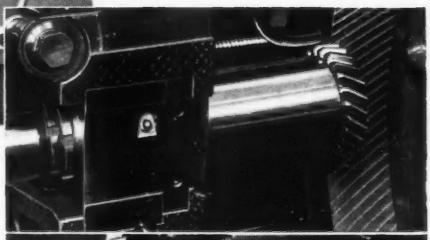

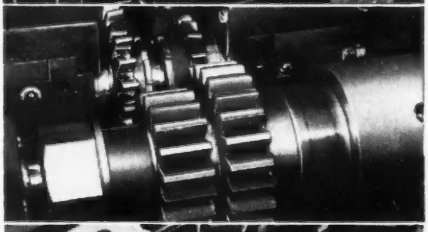

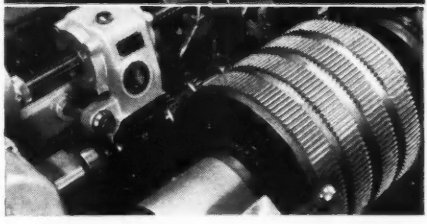

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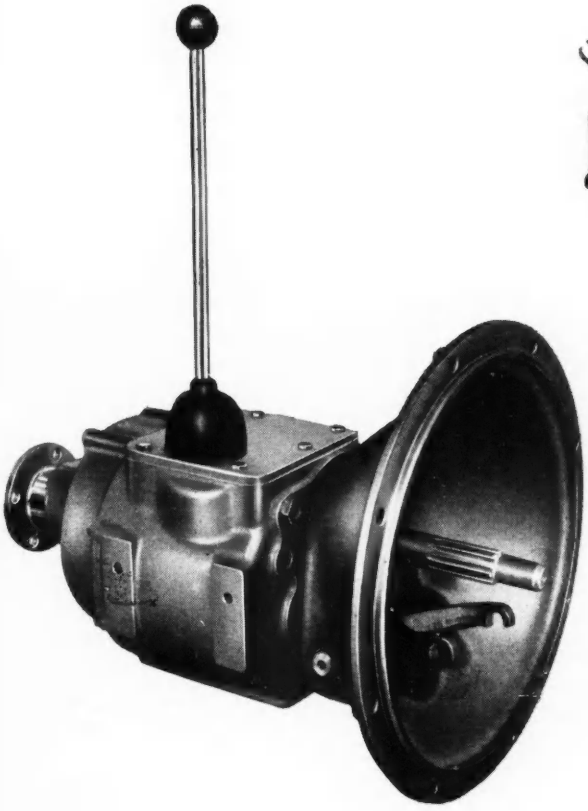

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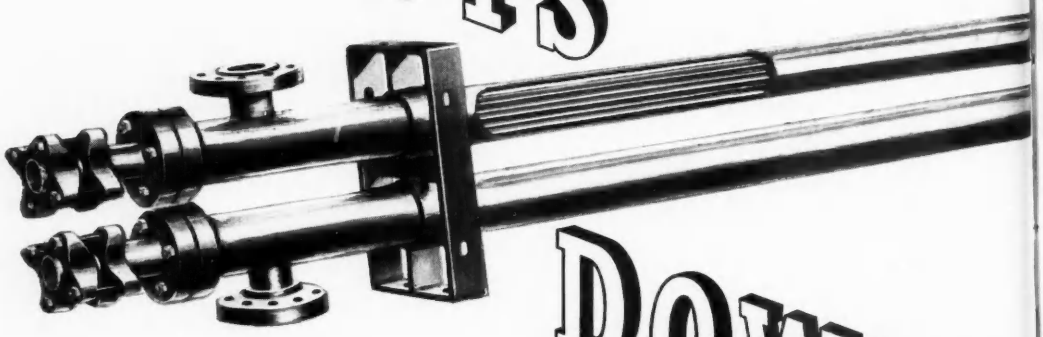

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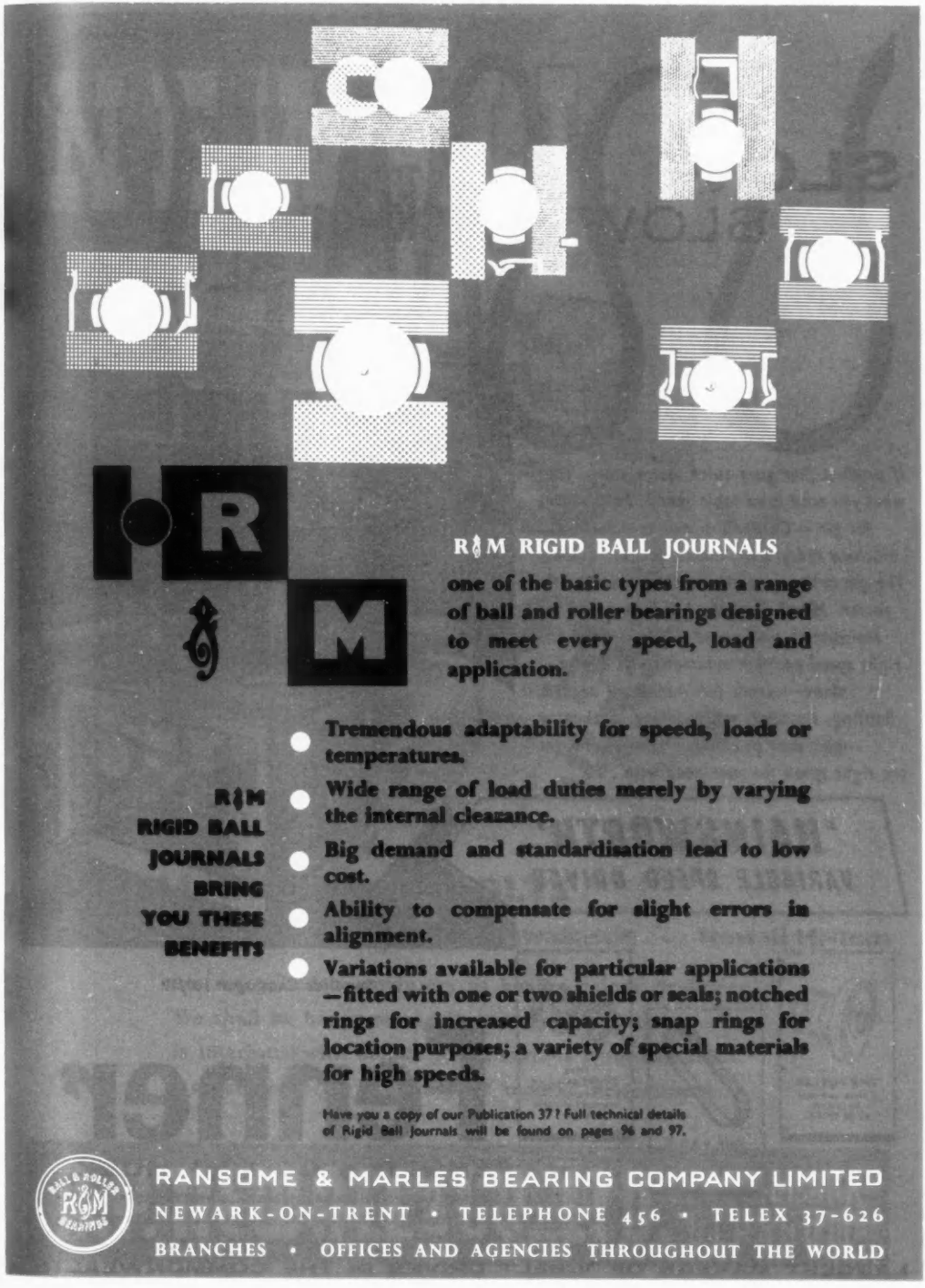

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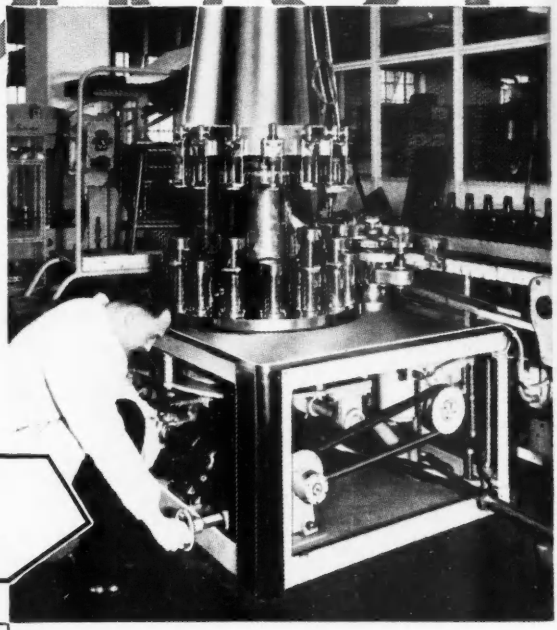

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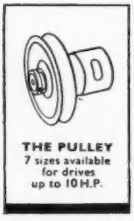

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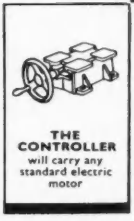

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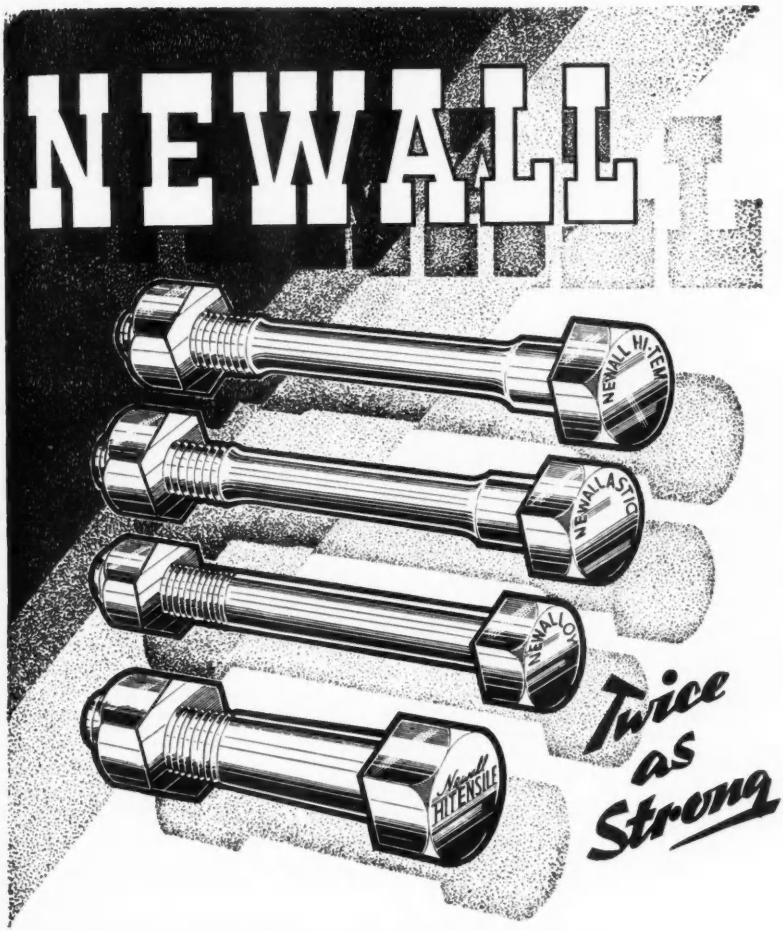

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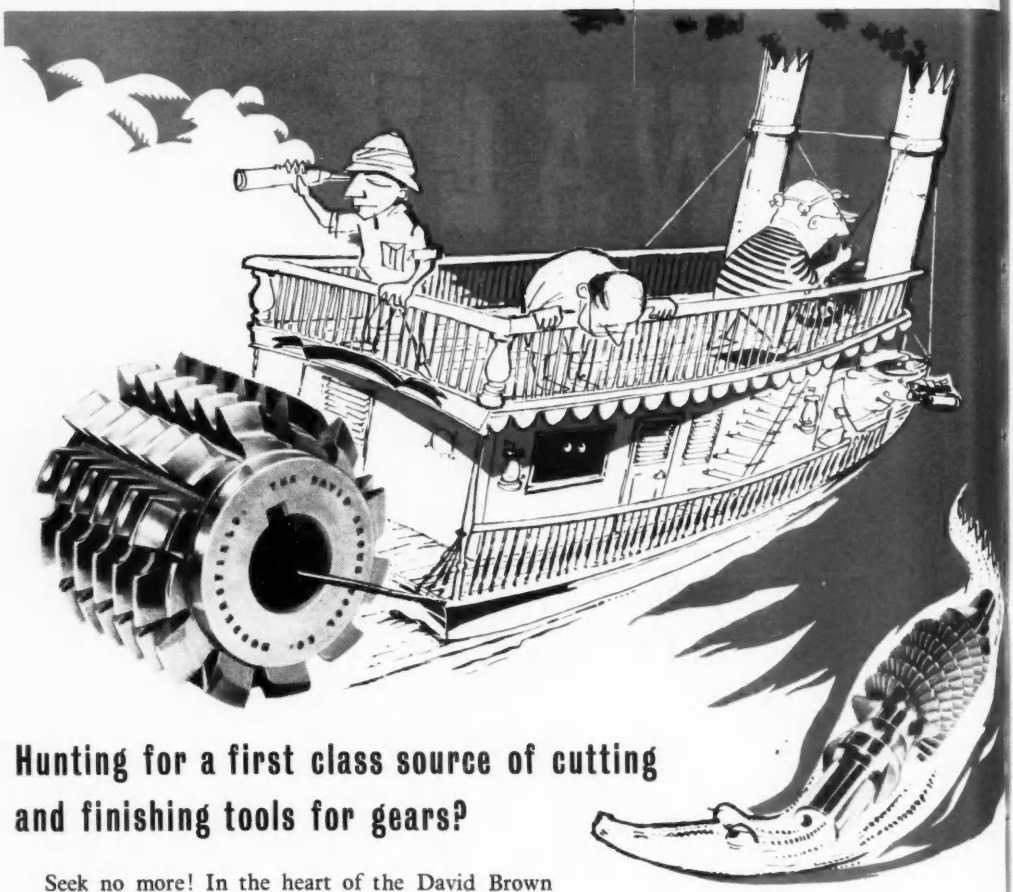

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A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *SIMULATED NUCLEAR FUEL-ELEMENT HEAT-TRANSFER TEST LOOPS*

Nuclear reactor performance depends greatly on the ability of the coolant to remove the heat generated in the fuel elements, and it is therefore important to establish experimentally the heat-transfer and fluid-flow characteristics of proposed new fuel designs. For this purpose, it is of advantage to use a simulated fuel-element heat-transfer loop, which can subject full-size prototypes to reactor operating conditions. In this test loop, use is made of direct current, instead of nuclear fission, to generate heat in the fuel elements. In this way, precision data can be obtained at a sharply reduced cost and without the need for bulky shielding devices and procedures. The fuel prototype can be fabricated from any material having the desired electrical resistance and mechanical properties, but the fact that direct current generates heat uniformly, instead of non-uniformly as in actual reactor fuel elements, must be taken into account when designing the test loop or when evaluating the data.

Such a loop can be used to determine heat-transfer coefficients, maximum heat flux, two-phase pressure drop, and other characteristics of various fuel-element geometries. Other investigations include simulation of reactor casualties, such as power transients, incidents caused by loss of coolant and loss of flow, and observation of heat-transfer behaviour during incidents. In one such system, an immersion heater, mounted in the lower head of a steam pressurizer, maintains a preset loop pressure, the use of a steam pressurizer being chosen in preference to the accumulator method of pressurization, because it is more stable. Automatic pressure regulation is provided by control of power to the immersion heater.

From *Nucleonics*, U.S.A., May 1960, pp. 110, 112, 114–115.

● *NEW INORGANIC GLASS COMPOSITIONS*

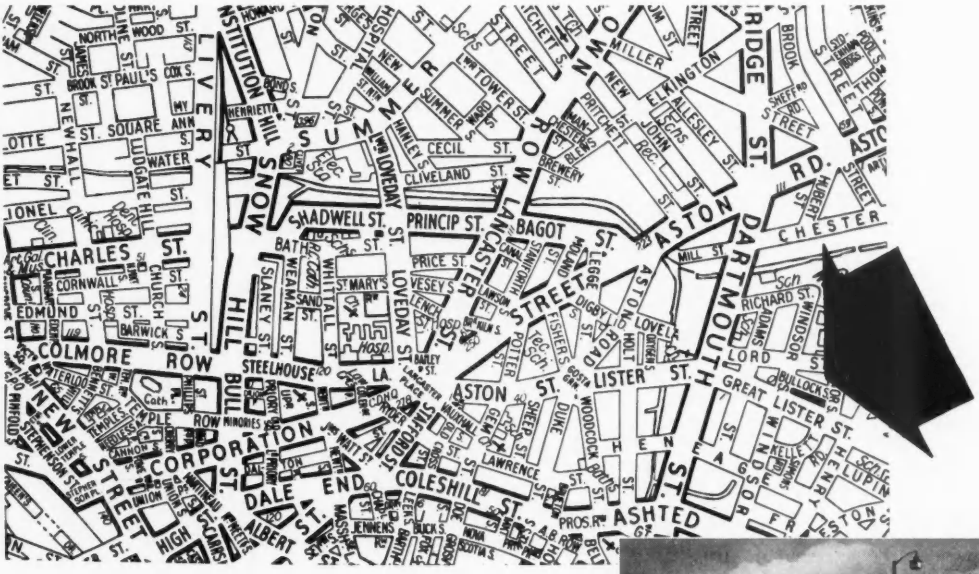
A new series of recently developed inorganic glass compositions, some of which are liquid at room temperature, is composed of varying proportions of arsenic, sulphur, and bromine. Previous work on compositions of arsenic, sulphur or selenium, and thallium had led to the production of glasses which softened somewhat above room temperature, and became fluid enough to be used for dip-coating at temperatures between 125 and 350°C. The substitution of iodine for thallium in the sulphur compositions later led to the production of glasses with somewhat lower softening points, several of them softening below room temperature, while a few were highly fluid at temperatures below the boiling point of water.

The new ternary compositions with bromine show even lower softening and high-fluidity temperatures, several being as fluid as glycerine at room temperature. Nevertheless, they are glassy solids at lower temperatures, show conchoidal fracture like silicate glasses, and exhibit no extensive ordering in their structure. Wide ranges of softening points and chemical compositions can be achieved. For example, substantial amounts of bromine (up to 20%) can be used in the ternary mixture without dropping the softening temperature. With the addition of greater amounts of bromine, softening and high-fluidity temperatures decrease to room temperature and below. Outside the area of glass formation in the phase diagram, crystalline materials are formed, or else the compositions precipitate sulphur. However, within a large area of composition variation, these glasses show no tendency towards instability over extended periods of time. These new compositions, which are not yet commercially available, are relatively stable towards acids, but are attacked by alkalis.

From *News from Bell Telephone Laboratories*, U.S.A., April 25, 1960.

● *AXIAL VIBRATION AND HUM IN SMALL INDUCTION MOTORS WITH BALL BEARINGS*

When small induction motors fitted with rolling bearings are running under no-load conditions, axial vibrations of the shaft are often observed. This is a particularly frequent occurrence in the case of motors equipped with single-row ball bearings and is often accompanied by a noticeable hum. No research into the causes of these objectionable features appears to have been carried out as yet, and it is therefore the object of a recent Japanese investigation to undertake a systematic study of this problem. This investigation shows that axial vibration is extremely complex in nature. Thus, the vibration, which has a frequency of 300 to 500 cps, becomes more pronounced in winter or when a grease with poor lubricating qualities is used. Furthermore, vibration can sometimes



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be initiated merely by a slight tap on the shaft, though it disappears if axial preloading is imposed on the ball bearings.

From an analysis of these phenomena, based on tests on a $\frac{1}{2}$-hp motor running at 1500 rpm and equipped with ball bearings having a clearance of 8 to 15 microns, it is concluded that the axial vibration encountered is a free vibration of a system composed of the rotating mass of the rotor and a non-linear spring characteristic in the axial direction. The spring characteristic contains two regions, one of which is asymmetrical and the other symmetrical, it being possible to calculate the frequency of vibration in the symmetrical region on the basis of the theory of elasticity and non-linear vibration. Insofar as hum is concerned, it is concluded that hum increases when the natural bending frequency of the motor brackets is $j/2$ times the frequency of vibration, where j is a positive integer, these cases corresponding to the unstable region in the vibratory system of Mathieu.

From *Bulletin of the Japan Society of Mechanical Engineers*, February, 1960, pp. 81–87.

● *IMPROVED HEAT-RESISTANT DIELECTRICS*

A recently patented improved dielectric material with high permittivity and high resistivity, even at high temperatures, consists of a sintered composition of oxides of strontium, bismuth, and titanium, in which the total number of strontium and bismuth atoms is not greater than, or is substantially equal to, the total number of titanium atoms. The ratio of the number of strontium atoms and 1·5 times the number of bismuth atoms is at least equal to the number of titanium atoms, while the ratio of the number of strontium atoms to the number of bismuth atoms lies between 9 : 1 and 1 : 10, but should preferably not be greater than 2 : 1. The dielectric is prepared by mixing the oxides, or suitable precursors such as carbonates, calcining the mixture by heating it to a temperature of 1100°C, and grinding the calcined mixture with a ceramic binder to obtain a mouldable mass. This mass is pressed into the desired shapes and is sintered by firing to temperatures between 1200° and 1400°C, the range between 1200° and 1300°C being generally preferred. In order to obtain capacitors, electrodes are then applied to the sintered pieces.

Measurements conducted on such dielectric bodies incorporated in capacitors have shown values of the product of resistance and capacity exceeding 20 megohm-microfarads at 200°C, and in some cases as high as 2000 megohm-microfarads. The dielectric constants (permittivities) have also been found to be high, lying between 100 and 1500, and in most cases between 500 and 1200. The temperature coefficients are moderate in value and negative in sense, varying between zero and a decrease of 4% per °C in the dielectric constant.

The material is at present intended mainly for application in capacitors for use at high temperatures, especially high-value capacitors, e.g., up to several microfarads, which may be used for temperature compensation, the temperature coefficients of capacity being independent of the temperature.

From *Brit. Pat. Spec.* 834,076, The Plessey Company Limited, London, England.

● *ULTRASONIC TESTING FOR PARTICLE CONTAMINATION IN HYDRAULIC FLUIDS*

It is reported that the contamination of hydraulic fluids by solid particles as small as one micron can rapidly be assessed by standard ultrasonic equipment, suitably modified. A reflectoscope is the main measuring component of the system, which consists of an electronic circuit to generate pulses, a transducer to convert the pulses into ultrasonic sound and to reconvert reflected ultrasonic sound to electrical impulses, and an electronic circuit to amplify and display the reflected pulses on a cathode-ray screen, the basic principle being that an ultrasonic wave front travels through a homogeneous medium without reflection until it meets a discontinuity or change in density.

In practice, the transducer is acoustically coupled to the test fluid, sending a short burst of ultrasonic sound through it, the resulting reflected energy varying with fluid density, which itself depends on contamination. The transducer converts the reflected energy into electrical signals which are amplified and displayed on the vertical axis of the oscilloscope. This axis is calibrated by introducing particles of known size, the distance along this axis representing particle area. Repeating this sequence, a continuous display is obtained. The horizontal axis of the oscilloscope, on which particle distribution is read, is connected to a sweep circuit, so that the swept distance is proportional to the length of the fluid column being scanned. To prevent counting a particle more than once, a flowmeter controls the repetitive rate of the reflectoscope. This makes sampling rate proportional to flow rate, so that a particle is in the test area only long enough to be sampled.

From *Applied Hydraulics and Pneumatics*, U.S.A., May 1960, pp. 140–141.

● *CAESIUM DIODES FOR CONVERTING NUCLEAR HEAT TO ELECTRICITY*

It is possible that the true potential of atomic energy may eventually be realized with the use of plasma in conjunction with a nuclear reactor, the heat of the fissioning materials being converted directly into electric current.

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A caesium diode can be used for producing the plasma, in which case no caesium would be wasted, only uranium being consumed. While the intrinsic temperature of the fission process is millions of degrees, the actual temperature envisaged is 2000°C, i.e., roughly twice the operating temperature of nuclear reactors now in the project stage. The thermodynamic efficiency of an engine operating between 2000°C and room temperature is as high as 87%, indicating the potentialities of the system.

The caesium energy converter is a diode filled with caesium to provide high levels of ionization by the interaction of caesium with the hot cathode to form a plasma. In some general respects the caesium diode is a thermocouple, in which one metallic branch is replaced by the plasma. A thermocouple containing a plasma actually produces voltages as high as a thousand times those produced by ordinary thermocouples, so that a temperature difference of 1000°C will produce one volt, as compared with one millivolt obtainable with perfect metals. The caesium converter would be adapted to reactor design by suspending the fuel rod in a container to which a very small quantity of caesium has been added. The highest currents obtained so far in the laboratory have been 30 amperes per square centimetre of surface area delivered at about 1 volt—an extremely high power density.

From *SAE Journal*, U.S.A., April 1960, pp. 60–61.

● *REINFORCED FURANE-RESIN SYSTEMS*

Recent developments in furane resins have made it possible to achieve tighter, more complete cures, resulting in higher strengths than have hitherto been obtained with furane resins in reinforced-plastic structures. The physical properties of cured furane resins are influenced in part by the catalysts, the cure conditions, and the reinforcements used. These reinforcements, which are important to chemical equipment because of the added mechanical strength conferred, include carbon, graphite, acid-washed asbestos, silica, and glass fibres. When woven glass and asbestos fibres are used, the resin and catalysts are blended and applied to the cloth or batting *in situ*. As the cure takes place, preferably in the presence of air, the structure is built up to the desired thickness for strength and chemical resistance.

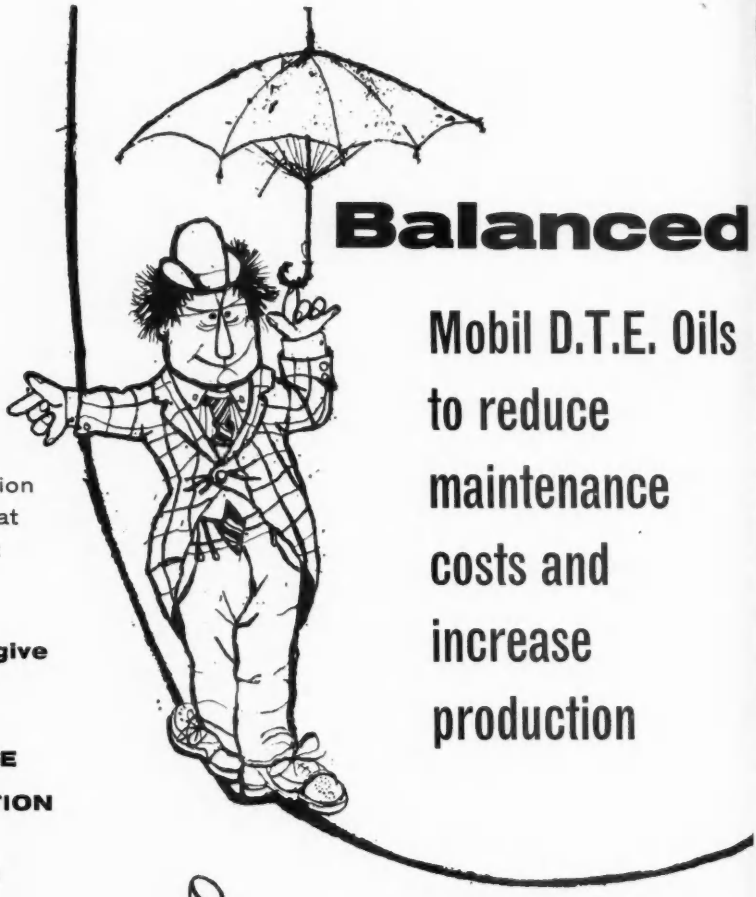
The effects of fillers added to the resin system vary, depending on their physical nature. Thus, large amounts of asbestos contribute considerably to strength, although chemical-resistance qualities are basically dependent on the furane resin. The pourability of the casting resin is decreased markedly with additions of asbestos fibres until a point is reached where the materials must be applied by trowelling techniques, while shrinkage during curing is decreased markedly, almost as a function of the percentage of asbestos added. Because of the current interest in glass-cloth reinforcements, tests have been carried out on glass-cloth laminates, and show that the physical properties of laminated fibre-glass structures fall off considerably during the first 24 hours when immersed in hot solutions, this being attributed primarily to the wicking action of the glass cloth and to simultaneous stress and chemical immersion. In commercial practice, this marked decrease in strength is circumvented by a resin-rich layer exposed to the solution or an organic-fibre surface layer to prevent contact of the chemical solution with the glass fibres.

From *Corrosion*, U.S.A., April, 1960, p.p. 26, 28

● *INFRA-RED HIGH-SENSIVITY PHOTO-THERMIC IMAGING SYSTEM*

Infra-red systems of sensing the heat energy radiated by a body and converting it into equivalent electrical signals that can be amplified and made visible to the human eye are not entirely new. However, whereas the traditional method is to use a sensitive crystal or infra-red cell to detect the radiation and a mechanical scanning system to make the image visible, a new system, called a photothermic image converter, is of an all-electronic nature, with the potential advantages of a more rapid response, higher sensitivity, and superior picture detail. In fact, the new system, which has been developed at the Westinghouse Research Laboratories, is sensitive enough to detect moving objects near room temperature when they exhibit a temperature difference of about 20°F, i.e., about the same temperature difference as that between the human body and the average room. In addition, the system is rapid enough to follow the movement of objects with the same speed as that of a normally visible object followed by the unaided human eye.

The heart of the new system is a specially developed detector, or retina, of high infra-red sensitivity. This retina is a sandwich only a few millionths of an inch in thickness, the middle layer of the sandwich comprising a support film of aluminium oxide, about 1 micro-inch in thickness, made by chemically dissolving away all the actual metal in a piece of suitably treated domestic-type aluminium foil and leaving only the thin layer of oxide coating on its surface. The front surface of the oxide support film is coated with an even thinner layer of nickel, deposited in such a thickness that it strongly absorbs infra-red radiation. The back surface of the film is coated with a thin layer of caesium-bismuth, which is capable of releasing electrons when



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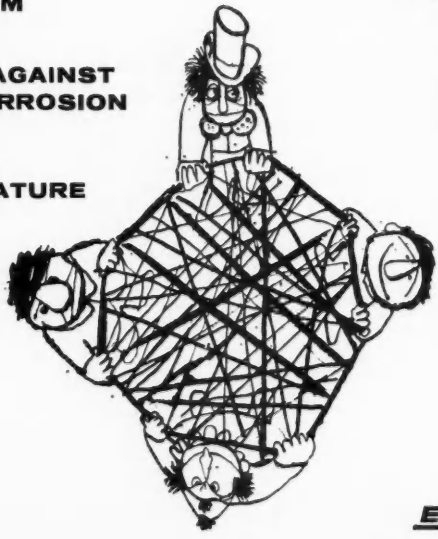

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light shines upon it. The ability of this photo-emitter to release electrons under the stimulus of light varies with temperature, changing by from 2 to 3% per °F. Consequently, to increase the overall sensitivity and performance of the detector, it is cooled to a temperature of −180°F.

In operation, the infra-red radiation from an object is focused on the heat-absorbing layer of the retina, forming a temperature pattern of the scene, which is transferred through the thin support layer to the photo-emitting caesium-bismuth surface, where it can be perceived merely by scanning the spot of light across the surface. As a result, the number of electrons flowing from any point on the surface is in exact conformity with the heat pattern on it. These electrical signals are then amplified and fed to a standard television picture tube, where a visible picture appears.

From *The Cornell Engineer*, U.S.A., April 1960, page 42.

● *IMPROVED METHOD OF MAKING FIBRES FROM MOLTEN MINERALS*

Several methods are in use for the production of fibres from mineral melts such as blast-furnace slag. In one such method, jets of molten slag impinge on a rapidly rotating disc, heated ceramic or steel discs being used for this purpose to prevent the melt from cooling too rapidly. In order to promote the formation of thin, long fibres, the jet is caused to impinge on a narrow zone at the edge of the disc, utilizing radial ribs arranged in the vicinity of the circumference of the disc. These centrifugal-disc processes have a number of disadvantages, owing to the high temperature of the heated disc and also because only a small annular area at the periphery of the disc can be employed, impairing not only the efficiency of the process, but also the quality of the fibres.

It has now been found, however, that, when disintegrating molten minerals to form fibres by a centrifugal process, satisfactory results can be achieved only if steps are taken to ensure that a thin air cushion is formed on the surface of the disc. It has also been discovered unexpectedly that the desired result can be obtained with cooled centrifugal discs. A recently patented process for making fibres from molten materials therefore comprises directing a jet of molten mineral eccentrically on to a horizontal disc which is cooled and rotated at such a speed that an air cushion is formed on its surface, where the molten jet breaks up into droplets, which are flung from the periphery of the disc in the form of fibres. The quality of the fibres is affected by the nature of the surface of the disc, which should have a certain roughness, such as that obtained by abrasion or filing. The greater the roughness, the greater must be the speed of rotation, e.g., from 6500 to 8000 rpm for a disc that has been roughened by filing. Centrifugal discs of any size can be used, with rotational speeds between 2000 and 15,000 rpm, depending on roughness and other factors, but particularly good results have been obtained with discs of from 400 to 500 mm in diameter, with the molten jet directed on to the disc at a distance of from 100 to 150 mm from the centre of the disc.

From *Brit. Pat. Spec.* 18. 836,339, Dortmund-Hörder Hüttenunion A.G., Dortmund, Germany.

● *ELECTRON SPIN RESONANCE SPECTROSCOPY AND ELECTRON PROBE MICRO-ANALYSIS*

Two new techniques of non-destructive testing and analysis involve the use of electron spin resonance and electron probe micro-analysis respectively. Electron spin resonance spectroscopy, which has now become a standard non-destructive testing method, is based on the use of unique radio-frequency techniques and electron spin resonance, which can be observed in any material having a sufficient resultant magnetic moment. Numerous materials have already been investigated with this instrument, including exchange catalysts, glass, crude oil, polymers, micro-organisms, asphalts, dyes, barium titanate, transition-element salts, irradiated materials, semiconductors, and solid-state materials.

The other new technique, electron probe micro-analysis, comprises two basic methods of non-destructive microchemical analysis. The first of these is X-ray micro-analysis, which is similar to X-ray analysis, but has the special feature that an electron beam can be focused down to extremely small areas, and the X-rays given off from a specimen on which the electron beam is focused can be analysed both quantitatively and qualitatively. The second method of electron probe micro-analysis consists of obtaining the microchemistry of entire areas, rather than those of small spots, this being affected by electron-scattering or electron-transmission techniques. Metallurgical specimens, semiconductors, and other materials can be analysed over regions of less than 1 micron in diameter, a resolution of about 0·1 micron being possible.

From *Nondestructive Testing*, U.S.A., May/June 1960, pp. 180–182.

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VOL. XXI No. 7 JULY, 1960

Design Data for Plastic Bearing Materials

By L. H. GILLESPIE and G. S. HUDSON

From *Iron and Steel Engineer*, U.S.A.,
Vol. 37, No. 4, April 1960,
pp. 151-157, 8 illustrations.

TEMPERATURE and deformation with time are not major factors when dealing with metals, but must always be taken into account when dealing with plastics. It is only during the last few years that sufficient data and experience have been accumulated to make it possible to compensate in design for the effects of these variables.

In the field of bearings, there are three plastics for which an intensive study of these design factors has been made, these being nylon resins, TFE-fluorocarbon resins, and, most recently, acetal resins. While not complete, sufficient information has been gathered to enable engineers to design a plastic journal bearing, with confidence in its successful performance. It will, of course, be appreciated that, just as the term "nylon" designates a family of polymers, the same is true of acetal and TFE-fluorocarbon resins. For this reason, the design information presented in this paper is based on data and experience obtained with specific compositions of these generic groups, best fitted for bearing applications. These materials are a nylon resin, an acetal resin, and various reinforced compositions of TFE-fluorocarbon resins of the properties listed in Table I.

From Table I, it will be seen that all three types of material are low conductors of heat, with approximately the same coefficient of thermal conductivity, although the addition of certain reinforcing materials to the TFE-fluorocarbon resins significantly changes this property.

The acetal resin has the highest yield point. Although decreasing slowly as the temperature increases, the yield point is still approximately 6000 psi at 200 F. The yield points of the reinforced compositions of the TFE-fluorocarbon resins are lower than those of the other two materials, and vary considerably with the percentage and type of reinforcement, typical reinforcing materials being glass, graphite, copper, and asbestos. Loadings vary from 10 to 50% by volume. From the standpoint of compressive strength alone, glass is one of the best additives. It can also be seen that the TFE-fluorocarbon compositions have the highest maximum continuous service temperature—a major design requirement in many applications.

The acetal resin, with its flexural modulus of 410,000 psi at 73 F, is the hardest and most rigid, though the nylon resin is tougher, as is evinced by its lower modulus and higher yield point. The reinforced TFE-fluorocarbon resins have uniquely low frictional properties, lower than those of any other non-lubricated material.

With regard to abrasion resistance, it may be said that Taber abrasion measurements show similar values for all three types of material. However, Taber measurements are not a measure of bearing performance but show only a relative abrasion resistance. In fact, in actual service, the nylon resin usually exhibits the highest abrasion resistance.

TABLE I: PROPERTIES OF THE PLASTIC BEARING MATERIALS CONSIDERED

Property	Nylon Resin at 2½% Moisture	Acetal Resin	Reinforced TFE-fluorocarbon Resins
Yield point at 73 F [psi]	8,500	10,000	850 to 1800
Maximum continuous service temperature [F]	250	180	500
Rockwell hardness	M59, R108	M94, R120	J63 to J80
Coefficient of thermal conductivity [BTU per in. per hr. per ft² per F]	1·7	1·6	1·7 to 20·0
Compressive stress at 1% strain at 73 F [psi]	2,000	5,200	100 to 200
Flexural modulus at 73 F [psi]	175,000	410,000	125,000 to 200,000
Coefficient of linear thermal expansion [in. per in. per F]	$5{\cdot}0 \times 10^{-5}$	$4{\cdot}5 \times 10^{-5}$	$2{\cdot}0$ to $5{\cdot}0 \times 10^{-5}$

Bearing Lubrication

Most plastic bearings operate dry or with only initial lubrication. Occasionally, there are instances where plastics are used with complete hydrodynamic lubrication. When plastic materials are selected for completely lubricated service, it is often for a supplementary reason. For example, the nylon and acetal resins will retain hydrodynamic lubrication with a minimum of lubricant, and this property is particularly desirable if there is a possibility of improper lubrication under operating conditions above the capabilities of a dry bearing.

The design information presented here is for dry, sleeve-type journal bearings but, although the data apply specifically to sleeve bearings, it appears that they can also be used conservatively for plain surface bearings. In this paper, the term "dry" means solvent-cleaned. In the test work upon which this design approach was based, the bearings and shafts were cleaned with carbon

tetrachloride to remove any traces of oil, since even a minute quantity of oil will improve the bearing characteristics of these materials. Design engineers can be confident that any oil on the bearing or on the shaft will contribute to even better performance.

Friction

Friction is of prime concern to bearing designers and, although it is as yet impossible to predict accurately a specific coefficient of friction for a specific bearing, sufficient data have been accumulated to indicate the approximate levels of friction under most bearing conditions. Thus, dry bearings of the nylon resin have a dynamic coefficient of friction of from 0·20 to 0·40, while bearings of the acetal resin have a slightly lower value, i.e., between 0·15 and 0·35. The static coefficient of the acetal resin is equal to its dynamic coefficient.

Bearings of a reinforced TFE-fluorocarbon resin have still lower dynamic coefficients of friction, in the range between 0·10 and 0·25 for speeds up to 100 fpm, levelling out at 0·26 for speeds above 250 fpm. Under light loads, i.e., less than 2 psi, the coefficient of friction will be as high as 0·45. These resins have an exceptionally low dynamic coefficient of friction at speeds which are lower than 20 fpm and under loads which are higher than 25 psi. Under such conditions, coefficients as low as 0·05 can be obtained with compositions containing a low percentage of reinforcing additive, while unfilled TFE resins against steel have the lowest coefficient of all, i.e., as low as 0·04. The static coefficient of friction of TFE-fluorocarbon resins is less than their dynamic coefficient; consequently, there is no slip-stick, resulting in smooth operation and easy break-way, and this can be an advantage in cases where operation is intermittent.

Load and Speed

As a guide, the *PV* limits for satisfactory operation of the three types of material under consideration are shown in Table II. In general, a length/diameter ratio of 1 : 1 is recommended for the limits given.

TABLE II: DESIGN *PV* LIMITS FOR THE BEARING MATERIALS

Material	Velocity Ranges			
	0 to 100 fpm	100 to 200 fpm	200 to 400 fpm	400 to 600 fpm
Nylon resin	3,000	2,600	2,200	1,800
Acetal resin	3,000	2,600	2,200	2,100
Reinforced TFE-fluorocarbon resins	9,600	9,600	9,600	9,600

Recent experimental work has more clearly defined the *PV* limits. Thus, while the limits shown in Table II are believed to be the maximum for sustained operation, there are many bearings which exceed these values. However, since most machines are subjected occasionally to unexpected loads and vibration, it is considered good practice for the designer to limit the design *PV*-values to only 75% of the rated limit, whenever possible.

Two equations permitting the determination of the limiting *PV*-values for bearings of either the nylon or the acetal resin have been established. For the nylon resin the limiting equation is $PV^{1.47} = 40{,}000$ and refers to a bearing clearance of 0·015 in. per in. For bearings of the acetal resin, the equation is $PV^{1.20} = 7600$ and applies for clearances up to 0·005 in. per in. Curves of these two equations are shown in Fig. 1, from which it can be seen that both curves are essentially equal, in spite of the difference in shaft clearance. With present knowledge, it is thought that both are about equal with respect to limiting *PV*-values. However, the acetal resin can probably reach the limiting conditions with slightly smaller shaft clearances, since the use of minimum clearance is closely related to the dimensional stability of the bearing material.

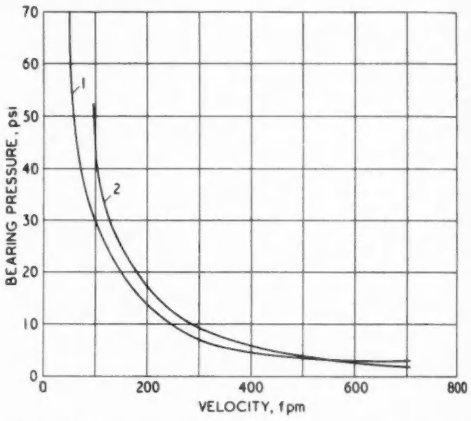

Fig. 1. Curves corresponding to equations for determining limiting *PV*-values for (1) the acetal resin with a bearing clearance of 0·005 in. per in., and (2) the nylon resin with a bearing clearance of 0·015 in. per in.

As indicated in Table II, the limiting *PV*-values given for TFE-fluorocarbon resins are for reinforced compositions. In this connection, it is interesting to note that a recent development in bearing applications comprises the weaving of oriented fibres of TFE resins into a fabric, the oriented fibres conferring an increased tensile strength. With such a fabric of TFE fibre, the limiting *PV*-value is as high as 25,000 in the velocity range up to 100 fpm. The use of this fabric composition is not, however, recommended for velocities higher than 100 fpm.

Clearances

Clearances for unsplit journal bearings are greater than for metals, in order to compensate for dimensional changes, and field work by the authors has shown that more than 50% of bearing problems are the result of insufficient clearance, an increase in clearance usually giving the required performance.

The resilience and vibration absorption of these plastic materials aid in overcoming any possible disadvantages of the use of larger clearances. Recent tests indicate that, for best performance, bearing clearances should be 0·005 in. per in. minimum, and it is preferable to specify up to 0·015 in. per in. In very few cases should a clearance of less than 0·004 in. per in. be specified, even for bearings with small inside diameters.

Temperature

The three types of plastics considered have a coefficient of thermal expansion about ten times that of metal. In the sizing of the bearing, allowance for thermal expansion or contraction must be made to ensure that clearances will be maintained at the operating temperature.

Dimensional changes with temperature vary with the design. For example, in a sleeve-type bearing in a rigid

housing, lowering the temperature by 100°F will cause a contraction in the clearance of 0·005 in. per in. Raising the temperature by 100°F will have little effect on the clearances. The reverse effect is true when the running surface is on the outside diameter of the sleeve. For optimum performance, the designer should size the bearing so that the proper clearances are obtained at the operating conditions.

Moisture Growth

An unfilled TFE-fluorocarbon resin does not absorb water and therefore does not undergo dimensional changes with variations in moisture. The reinforced compositions, however, may be subject to dimensional changes, depending on the nature of the additive and the percentage loading.

The acetal resin is affected only slightly by moisture and shows excellent stability over a wide range of temperatures. However, in water service, dimensional changes should be considered in the design. Fig. 2 gives a method of approximating dimensional changes due to temperature and moisture.

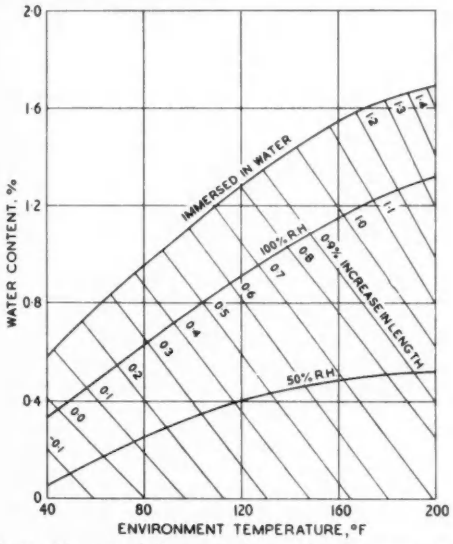

Fig. 2. Dimensional changes in the acetal resin as a result of humidity and temperature.

The nylon resin will absorb moisture from the atmosphere or from any other source. When design clearances are 0·015 in. per in., moisture changes and the resulting dimensional changes in air are not a problem but, when clearances are below 0·012 in. per in. or when the bearings are in water service, environmental effects should be considered in the design.

As moulded, the nylon resin normally contains less than 0·3% by weight of moisture. When exposed to air at 73°F and 50% relative humidity, mouldings of this resin will reach an equilibrium moisture content of 2½%. The rate of moisture absorption and the resulting rate of dimensional change for the nylon resin are low, as shown in Figs. 3 and 4.

A technique for minimizing dimensional changes in service is to precondition the bearings for the operating environment. Boiling in water or heating in a salt solution of potassium acetate in water brings the nylon

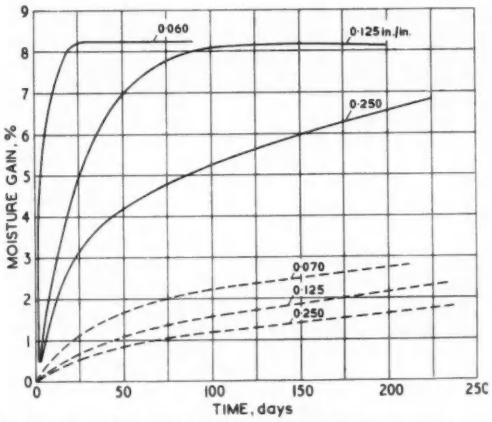

Fig. 3. Time required to pick up moisture for the nylon resin in water at 73°F (solid lines), and in air at 73°F and 50% relative humidity (dotted lines).

to an equilibrium moisture content at a faster rate and adjusts the bearings to the equilibrium dimensions of the anticipated service conditions.

Stress Relaxation

Injection-moulded bearings of the nylon or acetal resin may contain internal stresses induced during moulding. If these are high enough they may relieve themselves at elevated temperatures and result in slight dimensional changes of the bearing. To speed up these changes, and to eliminate in-service changes with possible impaired performance, the bearings should be annealed. Leaving the annealing oil on the bearing surface will improve the bearing characteristics by serving as initial lubrication.

The annealing should be performed by immersion in a hot oil which will not oxidize or chemically attack the plastic bearings. The parts should be submerged in oil at 320° ± 3°F for a period of time equal to one minute for each 0·020 in. of thickness.

Assembly

When press-fitting a bearing, allowance must be made for dimensional change during assembly. In a press fit,

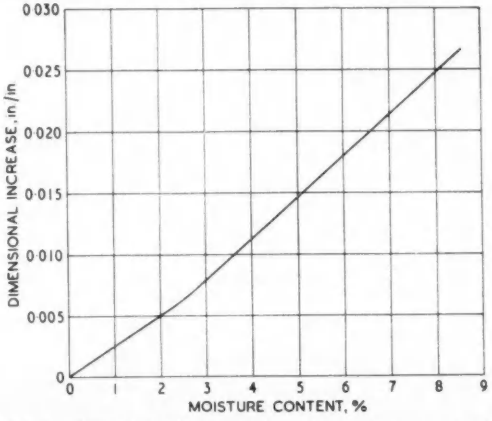

Fig. 4. Dimensional changes in the nylon resin as a result of moisture content.

the interference will translate almost completely into inside-diameter close-in or outside-diameter expansion, depending on which is the running surface. Compensation for this dimensional change should be included in the design. One of the bearings should not be constricted in the mounting. Prevention of thermal expansion in the axial direction may cause a reduction in radial clearance.

Surface Finish

The finish of the plastic surface is usually insignificant, and bearings moulded with a surface finish of about 25 to 50 micro-inches r.m.s. perform as well as bearings with a highly polished, smooth finish. The "break-in" period tends to reduce all bearing finishes to one finish for any given shaft.

It is the shaft finish which is critical because it is the harder material. A shaft finish of 25 micro-inches r.m.s. is considered to be the maximum for good wear characteristics, but one of 16 micro-inches r.m.s. or less is preferable. The shaft material is usually steel, and, other than for surface finish, it needs no special treatment or hardening. Other metals have been used, but there is very little information available with which to define parameters for either finish or hardness.

Deformation with Time

The operating limits of a plastic bearing are more sensitive to velocity than to bearing pressure, but there are compressive stress limits that should be considered in a well-designed bearing. The suggested design limits for compressive stress at 0·5% strain at a temperature of 200°F are 350 psi for the nylon resin, 800 psi for the acetal resin, and from 50 to 150 psi for the various reinforced TFE-fluorocarbon resins.

These limits for compressive stress are only a small percentage of the compressive strengths of the materials and are purposely limited to low values to prevent excessive deformation at high temperatures. For cool or light-duty bearings, deformation is negligible, but for bearings designed to operate near the limiting *PV* conditions, the design compressive-stress limits should be increased only after cautious experimentation. The acetal resin (because of its high strength and hardness) and a fabric TFE-resin material (owing to fibre orientation) are the least likely to creep under heavy load.

The characteristic of deformation with time under load or creep is always present in plastic materials and is a mechanism of yielding similar to that experienced with metals at high temperatures. For practical design purposes, the deformation at less than 1% strain after a one-year period reaches a magnitude approximately equal to that of the initial strain. To estimate total elongation, the initial strain may be multiplied by two. After a year's period, the creep rate becomes insignificant and is often immeasurable. Most of the creep is experienced within 1000 hr.

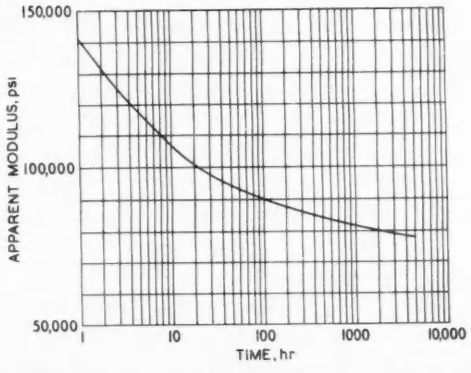

Fig. 5. Apparent modulus of the acetal resin as a function of time under load at a stress of 750 psi and a temperature of 185°F.

Fig. 5 shows the basis for this method of estimation, and is a curve of the apparent modulus of the acetal resin versus time at 750 psi stress and 185 F. Apparent modulus is defined as the stress divided by the sum of initial strain plus creep, and is a modulus of elasticity with an allowance for deformation under load with time. At time "zero", the apparent modulus is equal to the modulus of elasticity, as determined from a stress-strain diagram.

Service Temperature

As indicated in Table I, the nylon, acetal, and TFE-fluorocarbon resins considered are normally estimated to have maximum continuous service temperatures of 250°, 180°, and 500°F respectively. However, recent tests with the nylon and acetal resins have indicated that the shaft temperature should not exceed 175 F when operating at recommended *PV* limits. Reducing the *PV*-value will permit operation at higher temperatures. There is no indication that the 175°F limit applies to bearings of the TFE-fluorocarbon resins, which have been successfully applied at higher temperatures.

Since the bearing surface is the source of heat, it is the hottest part of the bearing assembly. The bearing housing is usually significantly cooler than 175°F. Because of this, a well-known rule-of-thumb has evolved, which states simply that, if the bearing holder is too hot to handle, it is too hot to use. This may not be the most scientific approach, but it frequently can be used in evaluating new bearing applications and designs. Excessive operating temperature is probably the best indication of imminent bearing failure.

Plastic bearings should always be designed with a view to utilizing the most efficient means of transferring heat away from the bearing surface, the usual path of conductance being through the steel shaft. It is also desirable to make the bearings as thin as practical, in order to increase the heat-transfer rate to the housing. Thicknesses of $\frac{1}{16}$ in. or less are used successfully. If the parameters of design so far outlined in this paper are followed, excessive heat will normally not be a problem. Nevertheless, it should be remembered that a hot bearing is an indication of rapid wear.

Wear

As yet, it is not possible to predict wear rates accurately. However, there is considerable evidence to indicate that properly designed bearings will wear at a rate of approximately 0·005 in. or less in 5×10^6 cycles. Usually, wear rates are considerably lower, especially if the bearings are initially lubricated. Because it is impossible to predict wear accurately, prototype testing of new bearing designs under actual or simulated service conditions is strongly recommended. Prototype samples are relatively easy to obtain, since all three materials are available as rod stock and can be machined with standard metal-working tools.

Like all bearings, plastic bearings should be "broken-

(*Concluded on page 85*)

Methods of Improving Weld Quality by Ultrasonically Vibrated Weld Pools

By A. A. Erokhin and L. L. Silin

From *Svarochnoye Proizvodstvo*, Russia,
No. 5, May 1960,
pp. 4-7, 7 illustrations.

Considerable research has been carried out by various investigators during the past few years into the effects of imparting vibrations to molten metal during the process of crystallization, and it has invariably been found that such vibrations reduce the gas content, refine the primary grain structure, and improve the mechanical properties of the metals concerned. Most of these investigations have been in connection with the influence of low-frequency vibrations (25 to 50 cps) on the properties of ingots and castings, but a considerable amount of evidence is also available on the influence of low-frequency vibrations on the properties of welded joints. Thus, it is known that, when vibrations at these frequencies are imparted to the weld pool, the impact strength of the welds substantially increases, owing to the partial transformation of dendrites into smaller equiaxial crystals, and this improvement in impact strength, as well as in some other mechanical properties, is more pronounced at increased vibration intensities.

The basic relationship between the intensity of vibration I and the mass density of the medium ρ, the speed of the sound wave c, the amplitude A, and the frequency f of these vibrations can be expressed as

$$I = 2\pi^2 \rho c f^2 A^2 \quad [\mathrm{W/cm^2}]$$

It can be seen from this relationship that, for a given metal, the vibration intensity I can be increased only by increasing the frequency f and the amplitude A of the vibrations imparted to the weld pool. However, if the amplitude is excessively large, the metal will spatter from the weld pool and, in general, the conditions for good weld formation will deteriorate sharply. On the other hand, it is extremely difficult to increase the vibration frequency by such means as mechanical vibrators, which necessarily have large moments of inertia. It is therefore apparent that one solution to this difficulty lies in the application of ultrasonic vibrations, i.e., at much higher frequencies. However, the wide use of this method is greatly hindered by the unsuitability of existing equipment and processes for imparting ultrasonic vibrations to the weld pool.

In order to study the metallurgical effects of imparting ultrasonic vibrations to weld metal and to find suitable methods which can be applied to various welding processes, a series of tests has been carried out in Russia. For studying the process of solidification of metals subjected to ultrasonic vibrations, use was made of cast aluminium specimens of 500 or 1000 gm weight and 50 mm diameter. Various methods of imparting the vibrations were employed and, after solidification, the grain structure of each specimen was examined. The best results were obtained when use was made of a method in which the vibrator was in direct contact with the molten metal, as described below. Under optimum conditions, the tensile strength of the specimens was found to increase from 6·0 to 9·9 kg/mm², while elongation was decreased from 34 to 26% and the reduction in area from 45 to 32%.

In general, good results were obtained when the ultrasonic vibrations were imparted continuously immediately after pouring and were stopped prior to the initiation of crystallization, as it has been found that, if the vibrations are continued after crystallization commences, the beneficial results of the process are greatly impaired. As crystallization of the metal does not commence until from 10 to 20 sec after pouring, there is ample time to impart these vibrations and to stop them, since the beneficial action of these vibrations can be achieved in from 1 to 3 sec.

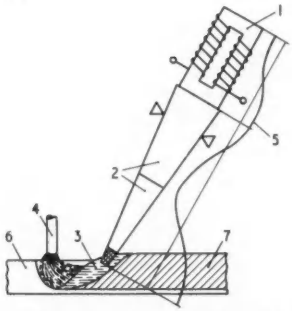

Fig. 1. Schematic arrangement of equipment for imparting ultrasonic vibrations directly to the weld pool.
(1) Magnetostrictive transducer.
(2) Horn.
(3) Weld pool.
(4) Electrode.
(5) Curve of vibration amplitude.
(6) Base metal.
(7) Weld seam.

From the results of initial tests with specimens of various configurations and with vibrations of different amplitudes, it has been established that the volume of recrystallized metal depends on vibration amplitude and that to each amplitude corresponds a definite volume of recrystallized metal, irrespective of the geometrical shape of the specimen. On the whole, these initial tests have conclusively proved the beneficial effects of ultrasonic vibrations on the grain structure of metals, and further work has been concentrated on developing practical methods for imparting these vibrations to the weld pool.

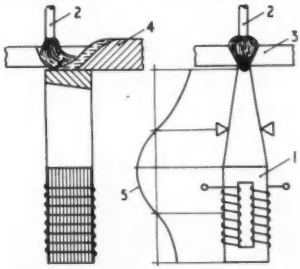

Fig. 2. Schematic arrangement of equipment for imparting ultrasonic vibrations to the weld pool, using a water-cooled vibrating support.
(1) Water-cooled vibrating support.
(2) Electrode.
(3) Base metal.
(4) Weld seam.
(5) Curve of vibration amplitude.

Of the various methods of imparting vibrations, by far the simplest is that in which the components to be welded are vibrated and the vibrations are transmitted indirectly to the weld pool. However, this method has a number of shortcomings, such as the comparatively high dispersion of vibration energy in the components to be welded, so that only part of the vibrations can be utilized, and also non-uniformity of the vibrations along the weld, causing stress concentrations and hence cracks to occur in the weld. As a result, this method can be recommended only for applications in which the weld pool is comparatively small and where no stresses or minimum stresses occur during solidification of the weld metal.

These difficulties can be overcome by a method in which the vibrations are imparted directly to the weld pool. In this case, owing to the reflections of the ultrasonic waves from the liquid/solid metal interface, the recrystallizing action of the vibrations is concentrated in the weld pool, and the risk of crack formation is greatly reduced. Fig. 1 shows schematically an arrangement based on this principle, and uses a magnetostrictive transducer (1) and a horn (2), the tip of which is immersed in the weld pool (3). During welding, the ultrasonic vibrator follows the movement of the electrode (4), the amplitude of the vibrations imparted being indicated by the curve (5).

Examination of welds obtained by this method shows that the welds consist of two distinctly different zones, made up of thin columnar crystals at the lower regions and of small equiaxial crystals at the central and upper regions, the zone of the equiaxial crystals coinciding with the region where the action of the ultrasonic vibrations is most manifest. This zone of equiaxial crystals can be improved by placing the tip of the horn as near to the centre of the weld pool as possible. Consequently, the tip must be made of a material with a high resistance to heat and to erosion in the molten metal. A number of tips have been tested for this purpose, including tungsten tips coated with aluminium oxide, and zirconia tips, but none has proved entirely satisfactory, owing to their limited service life and resistance to thermal shock. It is for this reason that, in methods based on direct contact of the vibrator with the weld pool, water-cooling has been found essential.

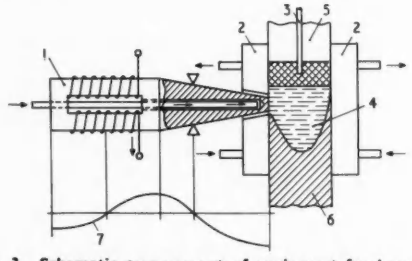

Fig. 3. Schematic arrangement of equipment for imparting ultrasonic vibrations in the case of electro-slag welding.
(1) Water-cooled vibrator.
(2) Water-cooled copper shoes.
(3) Electrode.
(4) Weld pool.
(5) Base metal.
(6) Solidified weld metal.
(7) Curve of vibration amplitude.

The use of water-cooled vibrators is especially suitable for welding processes with comparatively large weld pools as, with smaller weld pools, e.g., in conventional arc-welding, the water-cooled vibrator, which is necessarily of relatively large dimensions, causes substantial heat transfer from the liquid metal, with a deleterious effect on weld quality. However, water-cooling can be effectively used for smaller weld pools by means of a water-cooled vibrating support which is placed beneath the base metal and which moves along the weld parallel with the electrode. One such system is shown diagrammatically in Fig. 2, while Fig. 3 illustrates a special set-up designed for application to electro-slag welding machines. In this arrangement, the water-cooled vibrator (1) passes through the copper shoes (2) of the slag welding machine, and transmits vibration to these shoes and also to the weld pool (4), moving upwards during welding, together with the shoes.

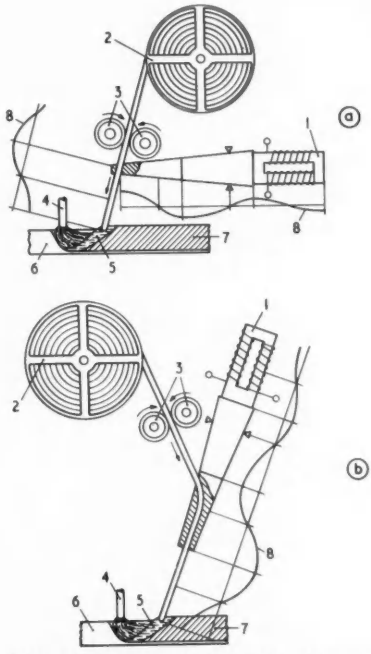

Fig. 4. Schematic arrangements of two set-ups for a universal method of imparting ultrasonic vibrations to the weld pool, (a) by laterally vibrated welding wire, and (b) by longitudinally vibrated welding wire.
(1) Vibrator.
(2) Reel of welding wire.
(3) Guide rollers.
(4) Welding electrode.
(5) Weld pool.
(6) Base metal.
(7) Weld seam.
(8) Curves of vibration amplitude.

All these arrangements constitute special applications, so that their use is limited. It was therefore found necessary to develop a more adaptable method of imparting ultrasonic vibrations to the weld pool. Two alternative arrangements for imparting ultrasonic vibrations to weld pools in any welding process are shown schematically in Fig. 4, in which use is made of a consumable welding wire which is caused to vibrate laterally (Fig. 4a) or longitudinally (Fig. 4b). The wires are fed from the reels (2) via guide rollers (3) to the weld pool (5) at a speed which is proportional to their rate of melting. It has been found that, with this method, welding speed is not adversely affected, and the composition of the weld metal can be controlled within wide limits. Tests have established that, with this universal method, the crystalline structure of the welds produced can be improved by increasing the rigidity of the welding wire; also, special care must be taken to position the guide rollers and the vibrator correctly.

Force-Transmission Characteristics of Simple and Composite Friction Systems

By K. Roth

(From *Feinwerktechnik*, Germany, Vol. 64. No. 4, April 1960, pp. 134-142, 25 illustrations)

Part II

It can be seen from eqs. (1′), (2′), and (3′) (see July issue, p. 113) that the slope of the transmission factor λ is always positive for the simple friction systems considered, i.e, F_R increases as μ is increased. This is fully in accordance with experience, which indicates that, with increased coefficients of friction, the forces which can be transmitted also become greater. In composite systems, however, this is not always the case.

Composite Friction Systems

If a system has, for instance, two coefficients of friction μ_1 and μ_2, and $\partial\lambda/\partial\mu_1$ is negative, then the force transmitted by friction will become smaller as μ_1 is increased.

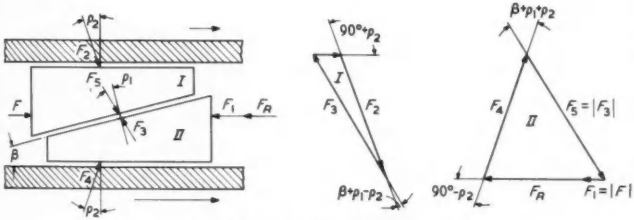

Fig. 9. Composite friction system (4).

An example of a composite arrangement (system (4)) is shown in Fig. 9. This system again has a transmission factor $\lambda = F_R/F$, but this factor is a function of the two independent variables μ_1 and μ_2, μ_1 representing the coefficient of friction between the sliding blocks, and μ_2 the coefficient of friction at the outer bearing surfaces.

From the equilibrium conditions it follows that

$$F_3/F = \cos\rho_2/\sin(\beta + \rho_1 - \rho_2)$$
$$\text{and } (F_1 + F_R)/F_5 = \sin(\beta + \rho_1 + \rho_2)/\cos\rho_2$$

Since $F_5 = |F_3|$ and, by definition, $F_1 = |F|$, the transmission factor of the system can be expressed as

$$\lambda = 2\sin\rho_2\cos(\beta + \rho_1)/\sin(\beta + \rho_1 - \rho_2) \quad \ldots \quad (8)$$

where ρ_1 and ρ_2 are the angles of friction (with $\mu_1 = \tan\rho_1$ and $\mu_2 = \tan\rho_2$) and β is the angle of the taper of the sliding blocks. Whereas β and ρ_2 are positive values in the particular arrangement considered, ρ_1 can also be negative. Hence, the shape of the λ-curve may vary considerably. With $D = \beta + \rho_1 - \rho_2$, the limiting condition is

$$\lim_{D \to 0} \lambda = +\infty$$

so that system (4) can be made to be self-sustaining. In the range $-\pi/2 < D < 0$ the system will have a falling characteristic for increasing values of ρ_1 (with $\rho_2 = \text{const.}$), whereas a rising characteristic will be obtained for increasing values of ρ_2 (with $\rho_1 = \text{const.}$).

If a composite friction system has both rising and falling characteristics, it is conceivable that, with appropriate design, it is possible to produce conditions such that the variations in the coefficients of friction will compensate each other. Before examining this possibility, it is useful to consider the composite system (5) (Fig. 10), this being an inversion of system (4).

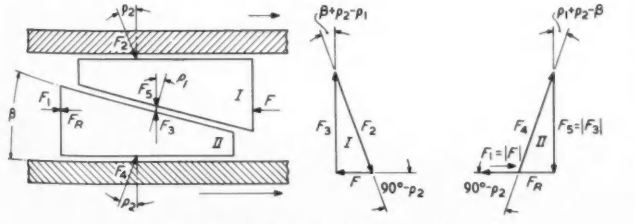

Fig. 10. Composite friction system (5).

At first sight, system (5) appears to be similar to system (2) as regards its functioning. However, this is so only under certain conditions, related to the variable angle of friction ρ_2. With a derivation similar to that used for system (4), the relations obtained are

$$F_3/F = \sin(90 - \rho_2)/\sin(\beta + \rho_2 - \rho_1)$$
$$\text{and } (F_R - F_1)/F_5 = \sin(\rho_1 + \rho_2 - \beta)/\sin(90 - \rho_2)$$

With $F_5 = |F_3|$ and $F_1 = |F|$, the transmission factor of system (5) is

$$\lambda = 2\sin\rho_2\cos(\beta - \rho_1)/\sin(\beta + \rho_2 - \rho_1) \quad \ldots \quad (9)$$

If β and ρ_2 are positive, and $E = \beta + \rho_2 - \rho_1$, the locking condition is initiated when

$$\lim_{E \to 0} \lambda = +\infty$$

Outside the range of self-sustained engagement (Fig. 11), when $\pi/2 > E > 0$, the λ-characteristic rises more markedly with increasing values of ρ_1 (with $\rho_2 = \text{const.}$); it rises less rapidly with increasing values of ρ_2 when $\rho_1 = 5{\cdot}71^\circ$ ($\mu_1 = 0{\cdot}1$), and falls off rapidly with increasing values of ρ_2 when $\rho_1 = 11{\cdot}31^\circ$ ($\mu_1 = 0{\cdot}2$). In the range where locking is possible (Fig. 12), when $-\pi/2 < E < 0$, λ increases fairly gradually when ρ_1 increases (with $\rho_2 = \text{const.}$), and falls off rapidly as ρ_2 is increased (with $\rho_1 = \text{const.}$). Thus, system (5) can have both rising and falling characteristics at the same time.

If an endeavour is made to obtain a constant friction force in spite of variations in the coefficients of friction, the λ-characteristics must be approximately horizontal, not only at a given point (i.e., a particular

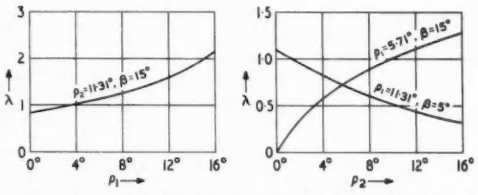

Fig. 11. Characteristics of the transmission factor λ for friction system (5), in the range of self-sustained engagement.

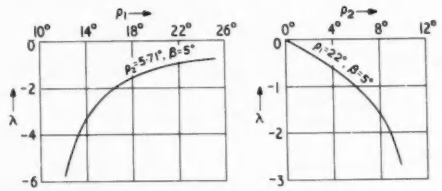

Fig. 12. Characteristics of the transmission factor λ for friction system (5), in the range where locking is possible.

configuration with angles of friction ρ_1 and ρ_2) but over a wider region.

It is therefore necessary that the ratio of the angles of friction $n = \rho_2/\rho_1$ (or the ratio of the equivalent angles of friction in a radial arrangement) be kept as constant as possible over a fairly wide region. With $d\rho_2 = n \mid d\rho_1 \mid$, eq. (8) for system (4) gives

$$\lambda = \sin n\rho_1 \cos(\beta + \rho_1) / \sin(\beta + \rho_1 - n\rho_1) \quad \ldots (10)$$

Evaluation of $d\lambda/d\rho_1 = 0$ gives the condition for a λ-curve with a horizontal region, i.e.,

$$n \sin 2(\beta + \rho_1) - \sin 2n\rho_1 = 0 \quad \ldots (10')$$

The sets of β-, ρ_1-, and n-values fulfilling this condition are readily determined for system (4) from the curves in Fig. 13.

Similarly, for system (5) eq. (9) yields

$$\lambda = 2 \sin n\rho_1 \cos(\beta - \rho_1) / \sin(\beta + n\rho_1 - \rho_1) \quad \ldots (11)$$

and its λ-curve will have a horizontal portion if

$$n \sin 2(\beta - \rho_1) + \sin 2n\rho_1 = 0 \quad \ldots (11')$$

Corresponding values of n and β for system (5), with ρ_1 as parameter, are also given in Fig. 13.

If, for example, in a system of type (5) the coefficient of friction between the sliding surfaces $\mu_1 = \tan \rho_1 = 0{\cdot}25$ ($\rho_1 = 14^\circ\ 2'$), it can be seen from Fig. 13 that, with $n = 2$, $\beta = 1^\circ\ 46'$. These values, introduced into eq. (11), yield curves of λ as a function of ρ_1, as shown in Fig. 14. It will be noted from this graph that the desired result, i.e., a horizontal region of the λ-curve, has been achieved at $\rho_1 = 14^\circ\ 2'$, or $\rho_2 = 28^\circ\ 4'$.

The procedure is similar when a λ-curve with a horizontal region is required for system (4). With $\beta = 30'\ 50''$ and $n = 0{\cdot}5$, for example, corresponding to $\rho_1 = 14^\circ\ 2'$ (or $\rho_2 = 7^\circ\ 1'$), the curve in Fig. 15 is obtained. Again, it droops slightly for larger values of ρ_2.

Unfortunately, these ideal shapes of characteristics virtually insensitive to variations in the coefficients of friction are not fully achievable, owing to other features of the composite systems.

Thus, consideration of Fig. 10 shows that in system (5) the upper sliding block *I* will try to move out of the wedging-engagement position for large values of ρ_2 (when

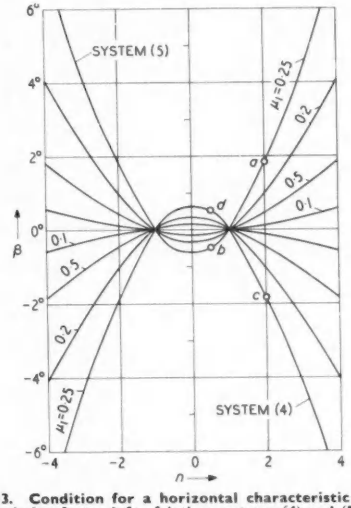

Fig. 13. Condition for a horizontal characteristic of the transmission factor λ for friction systems (4) and (5), with $\rho_2 = n\rho_1$ and $d\rho_2 \gtrless 0$.

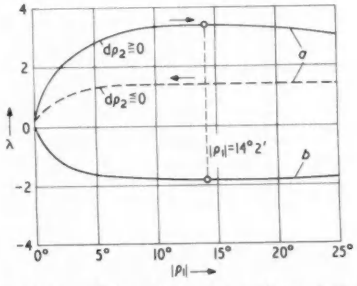

Fig. 14. Characteristics of the transmission factor λ for system (5), with a horizontal region at the operating point, curves *a* and *b* corresponding to points *a* and *b* in Fig. 13.

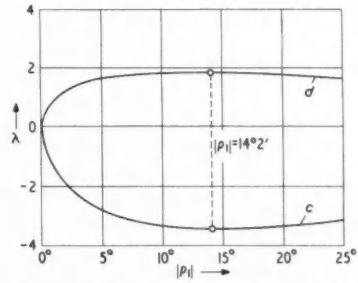

Fig. 15. Characteristics of the transmission factor λ for system (4), with a horizontal region at the operating point, curves *c* and *d* corresponding to points *c* and *d* in Fig. 13.

$d\rho_2 \geqq 0$), since block *I* is held back by the resultant friction force F_R. This type of equilibrium was assumed in deriving the expression for the characteristic. When ρ_2 becomes smaller, however, the blocks have the opposite tendency as a result of the forces F and F_1, i.e., they tend to become locked together to an increasing extent by wedging action. The angle of friction ρ_1 changes its sign, and, when equilibrium occurs with $d\rho_2 \leqq 0$, the

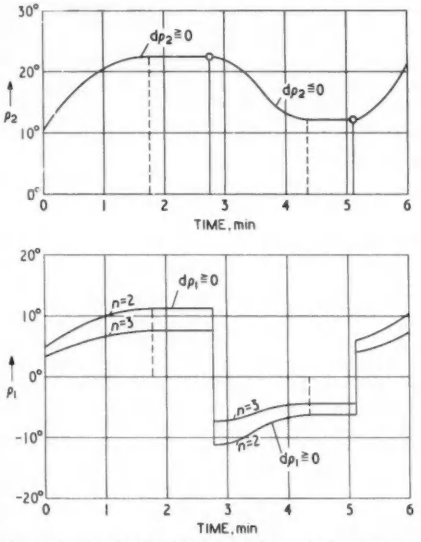

Fig. 16. Variations in the friction angles ρ_2 and ρ_1 with time for values of $n = 2$ and $n = 3$.

transmission factor of system (5) is obtained as

$$\lambda = 2 \sin \rho_2 \cos (\beta + \rho_1) / \sin (\beta + \rho_1 + \rho_2) \quad . . \quad . . (12)$$

The sequence of events is illustrated in Fig. 16. The angle of friction ρ_2 in the upper diagram can have any arbitrarily assumed value, with rising, constant, and decreasing trends. At points where $d\rho_2$ has a change of sign, ρ_1 also changes its sign. The sudden jump of ρ_1 at positions of discontinuity is less pronounced when n is large (see also Figs. 14 and 17).

For increasing or decreasing values of ρ_2, two different characteristics are obtained, as shown by the solid and dotted lines (*a*) in Fig. 14. For ρ_2-values with a decreasing trend, the condition for a horizontal region, in the case of system (5), can be derived from eq. (12) as

$$n \sin 2 (\beta + \rho_1) - \sin 2n\rho_1 = 0 \quad . . \quad . . \quad (12')$$

System (4) can be treated in a similar manner. From Fig. 9, however, it is apparent that ρ_1 will not change its sign when ρ_2 is varied, as long as the latter remains positive. A change of sign of ρ_1 could possibly occur if an attempt were made to release the clamping or wedging action via the blocks *I* and *II*.

The jump at the transition from increasing to decreasing values, shown in Fig. 16, is of course also present in non-compensated systems, and in simple systems if bearing friction is taken into account. For full compensation of the coefficients of friction, it would be necessary to combine two composite systems, one to be effective for increasing values of ρ_2 and the other for decreasing values of ρ_2.

Fig. 13 also shows pairs of β and n values for which $\beta < 0$. If these values are substituted in the expressions for the transmission factor, the disengaging forces can be obtained. In compensated systems, however, these disengaging forces are to a considerable extent independent of the variable coefficient of friction, as shown by curve (*c*) in Fig. 15.

The important result of this analysis is that the shape of the force-transmission characteristic can be suitably modified by synthesis of various friction systems. Below the self-locking condition, the characteristic is useful to obtain particular force-transmission properties; above this limit, it will serve to determine suitable disengaging forces. Thus, the force-transmission factor is suitable not only for characterizing the particular features of friction systems, but also for the synthesis of new types of composite systems mainly dependent on friction. Friction clutches, mechanical amplifiers, and mechanical speed governors are examples of systems to which the above can be applied.

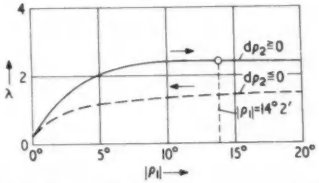

Fig. 17. Characteristics of the transmission factor λ for system (5), with a horizontal region at the operating point and with $n = 3$, the solid line referring to a rising tendency of ρ_2 and the dotted line to a falling tendency of ρ_2.

Finally, it may be recalled that the transmission factor is also dependent on the design factors. If these are variable, it is possible to represent their influence on changes in friction force in the same way as for variations in the coefficient of friction.

Design Data for Plastic Bearing Materials

(*Concluded from page 80*)

in" for optimum wear characteristics. Fifteen minutes at one-half the service conditions are usually more than satisfactory for nylon or acetal bearings. With bearings of TFE-fluorocarbon resins, the time is even less. Very often, a 15-min break-in period is impractical from a production assembly standpoint. In such cases, it is good practice to reduce the design *PV*-value in order to lower the level of significance of the break-in period. An alternative to this is initial lubrication of the bearings with a few drops of oil, or, if the residual annealing oil is not removed from the bearing surface, the "break-in" period can be eliminated.

Selection of Materials

Often, no clear-cut indication exists regarding the material required for a particular bearing application. There are many situations where all three resins are applicable, and in these instances the selection becomes one of cost.

Bearings of nylon and acetal resins can be injection-moulded and are particularly attractive for mass-production assemblies. Bearings of reinforced TFE-fluorocarbon resins are usually more expensive in large quantities and are more often adapted to use on more specialized equipment.

Some bearing applications are clearly suited to the properties of one resin. For example, if low friction at high load and low speed is the design requirement, TFE-fluorocarbon resins are the most logical first consideration. If abrasion resistance is paramount, the nylon resin should be considered first. On the other hand, if maximum resistance to creep is called for, the acetal resin or TFE fabric is indicated.

A Review of High-Energy Forming Methods

By W. W. Wood*

In Part I of this review in our issue of June 1960, details were given of the various types of high-energy forming methods, which have been divided into large-mass methods, high-velocity methods, high-temperature methods, and induced sound-wave methods. In addition, the theory of plastic deformation of metals was discussed, including the effects of time dependence, temperature dependence, and hydrostatic pressure. In this concluding instalment, the mechanism of plastic flow is indicated, energy comparisons are made, and the limitations and applications of high-energy forming methods are described.

Part II

The effects of time dependence, temperature dependence, and hydrostatic pressure in connection with the theory of plastic deformation of metals have already been considered. Still another factor that must be taken into account is the mechanism of plastic flow in the high-energy forming methods previously described.

Mechanism of Plastic Flow in Metals

The principal mechanism of plastic flow in metals is slip. Plastic slip varies considerably with a number of factors, such as the material used and the temperature, stress, and rate of strain. Insofar as a metal is concerned, the variable determining slip is its atomic structure, i.e., whether it has a body-centred cubic crystal structure, a face-centred cubic crystal structure, or a hexagonal close-packed crystal structure.

These basic structures determine the atomic density and hence the manner in which slip occurs, because it generally takes place on planes of the greatest atomic density. Materials with a body-centred cubic crystal structure, such as iron alloys, steel, and most refractory metals, have twelve slip planes, while those with a face-centred cubic crystal structure, such as most light non-ferrous alloys and most nickel-base alloys, have four slip planes, and those with a hexagonal close-packed crystal structure, such as magnesium, beryllium, and titanium, have only two slip planes. The number of slip planes does not necessarily determine the relative ease of deforming metals, but, in conjunction with another parameter, can be used to predict the ease of deformation. This other parameter is the critical resolved shear stress, which is the resolved component of stress acting parallel to a slip surface, causing flow to occur.

A qualitative comparison between a number of typical metals to indicate the relative interplay between the number of slip planes and the critical resolved shear stress is tabulated below.

Material	Number of Slip Planes	Critical Resolved Shear Stress	Ultimate Tensile Strength
Magnesium	2	Very low	Low
4908 Titanium	2	Medium	High
75S-T6 Aluminium	4	Medium	Medium
Molybdenum	12	High	Medium
Tungsten	12	Very high	High

The lower the number of slip planes, the more difficult is it for slip to occur in polycrystalline materials, because there are fewer grains to line up in the maximum shear direction (approximately 45 deg. to the direction of applied load). However, it should be noted that some materials with a high number of slip planes, such as molybdenum and tungsten, have a medium or high ultimate tensile strength, as indicated in the table above, because they have a high critical resolved shear stress. On the other hand, a material with only two slip planes, such as magnesium, will exhibit a low ultimate tensile strength because it has a low critical resolved shear stress. It should also be noted that temperature can change both the number of slip planes and the critical resolved shear stress of a material. Increased strain rates, alloying, and strain hardening generally increase the critical resolved shear stress, while increased temperature generally lowers it.

Another method of deforming metals is by what is termed "twinning". This mechanism is similar to slip in that atoms shift by a shearing action, but twinning is accompanied by a mass transfer of atoms across a broad segment of a grain, this atomic shift being proportional to the distance from the twinning plane. The process derives its name from the mirror-image effect noted about the twinning plane of symmetry.

The same parameters affecting slip also affect twinning; however, the temperature and speed of deformation have very little effect on twinning, compared with slip, as will be shown subsequently. For this reason, a considerable portion of the overall deformation at room temperature and below and at high strain rates is accomplished by twinning. Although twinning accounts for only small strains of the order of from 5 to 10%, its main function is in re-orienting grains into a more favourable position for slip, this being especially capable of accomplishment in the case of materials having a small number of slip planes, such as magnesium, beryllium, and titanium.

The final failure of a specimen is effected by one or both of two fracture mechanisms, i.e., ductile shear fracture and brittle grain-boundary separation, ductile shear fracture being the result of considerable slip occurring across slip planes. Brittle separation of metals generally occurs across the grain boundary as a result of critical normal stresses acting on the cleavage plane. In most metals, incipient fracture is initially due to grain-boundary separation, resulting in a crack which grows with final fracture by ductile shear.

Several theories have been suggested to explain brittle cleavage, the more prominent of which are based on minute cracks within a metal and the presence of dislocations. These types of imperfections are considered

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to be the reason for the lowering of the theoretical cleavage strength of metals by as much as 1000 : 1. Brittle cleavage is even less dependent on temperature than twinning; however, the speed of deformation has a more detrimental effect on cleavage because the effective normal stress is raised proportionately.

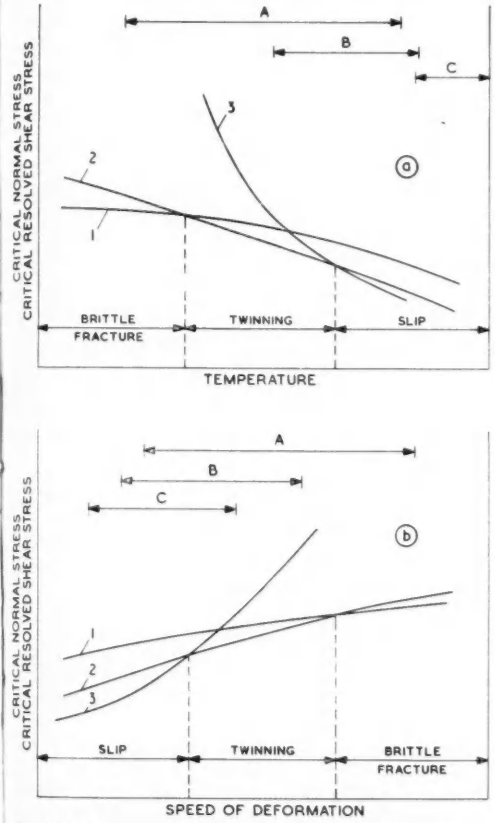

Fig. 12. Critical normal stress and critical resolved shear stress as functions (a) of temperature, and (b) of speed of deformation.
(A) High-velocity methods of forming.
(B) Large-mass methods of forming.
(C) High-temperature methods of forming.
(1) Brittle fracture.
(2) Twinning.
(3) Slip.

Because slip and twinning are shear mechanisms and brittle fracture is a separation mechanism, both slip and twinning are dependent on the critical resolved shear stress necessary to cause deformation, while brittle fracture is dependent on the critical normal stress. These relative relationships are illustrated in Fig. 12, which shows critical normal stress and critical resolved shear stress as functions of temperature (Fig. 12a) and of speed of deformation (Fig. 12b). From these graphs, it will be noted that there is a considerable dependence on temperature and speed of deformation for slip, while twinning and brittle fracture are only slightly affected by temperature and speed of deformation. The lowest critical stress will always determine the mode of deformation or fracture, as shown by the general areas of slip, twinning, and brittle fracture. It should be appreciated that practically all metals deform by slip or fracture by shear at high temperatures and low speeds of forming. Brittle fracture, on the other hand, determines the type of failure for low temperatures and high speeds of forming.

The graphs in Fig. 12 indicate that the high-velocity methods of forming, such as explosive and electrical-discharge forming, deform primarily by twinning and only secondarily by slip. These high-speed methods also show that most fracture is brittle, compared with the smaller amount of ductile shear fracture. The twinning deformation prevalent in these systems should be beneficial when forming metals with a hexagonal close-packed crystal structure, such as titanium and magnesium, provided that the speed of deformation and temperature are in the twinning zone of the graphs in Fig. 12. The more ductile materials, such as the stainless steels, probably form equally by twinning and slip, failure being of a ductile nature.

The large-mass methods of forming, such as the trapped-rubber and floating-piston methods, deform metals both by twinning and slip. Some brittle fracture may occur, but probably in the case of only a very few materials. On the other hand, the high-temperature methods of forming, i.e., those using integrally heated dies and those using hot fluids, result in a deformation that is almost entirely slip, though some twinning may occur in metals with a hexagonal close-packed crystal structure, where slip is impeded by the small number of slip planes. The slip deformation in these methods has been termed elevated-temperature creep forming and is dependent on the temperature, time, and number of dislocations in the metal.

Energy Comparisons

In assessing the forms of energy that can be utilized in the high-energy forming of metals, such parameters as pressure and temperature must be taken into account, together with the duration of forming, which determines the total energy.

Pressure

Pressure is one form of energy that is used to a large extent in all high-energy forming methods, though its magnitude varies considerably according to the method employed. For example, it has been reported that contact forming pressures as high as 7,000,000 psi have been obtained in explosive forming.

In explosive forming, the Kirkwood-Bethe theory relates the peak pressure p_{max} obtained from various shapes and types of explosive charges in accordance with the following equation:—

$$p_{max} = C\left(\frac{W^{\frac{1}{3}}}{x}\right)^{k}$$

where C is the explosive size constant, W is the weight of the charge, x is the distance of the charge from the point of pressure measurement, or stand-off distance, and k is the explosive shape constant.

Here, the primary variable is the explosive shape constant k, which generally varies from a maximum value of 3 for a point charge source to considerably less for other shapes of charges, e.g., a value of around 2 for cylindrically shaped charges. It will be noted from the equation that the pressure varies inversely with a power function of stand-off distance x and exponentially with the shape of the charge. The weight of the charge W and its explosive size constant C also control the pressure,

but to a lesser extent than the other two parameters. A qualitative picture of pressure as a function of stand-off distance x for explosive forming is shown graphically in Fig. 13, in which the shape of the curves is determined by the explosive shape constant k, the spacing of the curves by the explosive size constant C, and the pressure magnitude by the stand-off distance x.

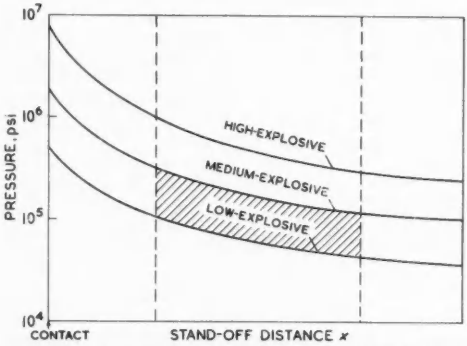

Fig. 13. Relationship between pressure and stand-off distance x when forming with explosives of different characteristics.

Water as a forming medium damps the shock waves and truncates the pressure-peak curves, so that impact and strain rates are lowered considerably. In Fig. 13 is illustrated a general working area (shown shaded) which gives pressure ranges from about 50,000 to 100,000 psi for large stand-off distances and from about 80,000 to 400,000 psi for closer stand-off distances. It can be seen from these values that, in general, insufficient pressure is obtained to reduce spring-back appreciably. In fact, it is only when higher-power explosives are used at relatively close ranges that spring-back and other distortions will be reduced.

Explosive and electrical-discharge forming produce considerably higher pressures than other methods of high-energy forming. In addition, they, together with hot-fluid forming, produce a very good pressure distribution because of the low coefficient of friction associated with water and hot fluids.

Temperature

Heat is another form of energy used in the high-energy forming of metals. As already indicated, heat lowers flow stress and increases elongation, resulting in an increase in the formability of a material. Toughness, or the ability of the metal to absorb shock loading, is also increased, and this is a great help in high-velocity methods of forming. However, more important than these factors is the increased creep forming that accompanies heat in high-temperature forming methods.

In high-velocity methods of forming, the temperatures involved are usually very low, seldom exceeding room temperature, except in explosive-gas forming, where the temperature may approach between 800° and 1000° F. It is true that explosive-gas forming can be extended to appreciable temperatures by preheating the parts, but limitations will, of course, be imposed on heat-loss rates in terms of insulation and heat input. In fact, only high-temperature methods of forming, i.e., with integrally heated dies or hot fluids, can produce temperatures which are high enough for elevated-temperature creep forming.

Forming Duration

Forming duration is an important parameter which determines the total energy in high-energy forming methods because, the longer the duration of both pressure and heat, the higher will be the energy input. Also, metals absorb forming energy in proportion to the rate at which pressure is applied and to the temperature of the part during forming.

Of the various methods of measuring forming duration, i.e., in terms of the total time to form the part, in terms of the workpiece velocity during forming, and in terms of the strain rate of the workpiece, measurement in terms of total forming time appears to be the most practical. On this basis, it may be said that, with high-velocity forming methods, the forming duration is of the order of as low as 0·001 sec. With drop-hammer, trapped-rubber, and induced sound-wave methods of forming, the forming duration is considerably longer, but is still appreciably less than 1 sec. The longest forming durations are obtained with high-temperature forming methods, i.e., from about 1½ to 7 sec with hot-fluid forming and from about 2 to 10 sec with integrally heated dies.

Comparison of Relative Energies

To provide a better comparison of the total energy associated with different high-energy forming methods, a three-dimensional graph is plotted in Fig. 14, which shows pressure, temperature, and forming duration for representative types of large-mass, high-velocity, and high-temperature methods of forming, the volume indicated for each forming method representing the amount of energy that can be put into the forming operation.

It can be seen from Fig. 14 that large-mass methods, such as drop-hammer forming, have the smallest amount of energy associated with forming, while high-velocity methods, such as explosive-water forming, have an intermediate amount of energy, and high-temperature methods, such as hot-fluid forming, have the largest amount of energy. Consequently, only those metals which can absorb energy rapidly can be formed to any appreciable extent by high-velocity methods. On the other hand, the only limitation to forming with high-temperature methods

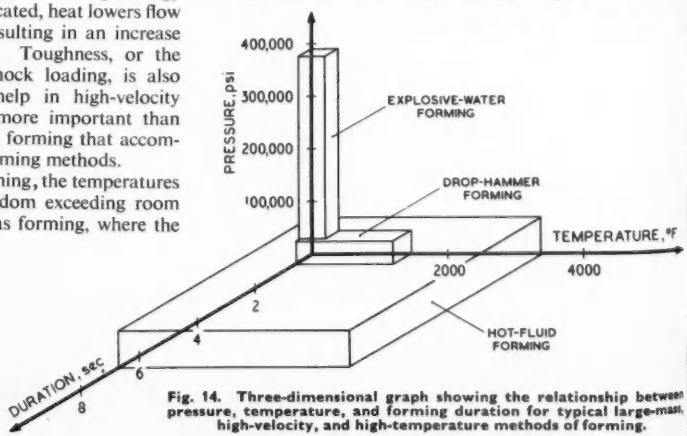

Fig. 14. Three-dimensional graph showing the relationship between pressure, temperature, and forming duration for typical large-mass, high-velocity, and high-temperature methods of forming.

is the plasticity associated with the material at the forming temperature and the metallurgical characteristics limiting this temperature.

It should not be inferred from Fig. 14 that the volume of energy shown is put into all formed parts by the three methods given. For instance, a considerable amount of heat can be lost in hot-fluid forming if proper insulation is not provided. Similarly, if pressure is applied too rapidly in explosive forming, the energy absorption of the metal will be very limited.

Limitations and Applications of High-Energy Forming Methods

Considerable data have been published on the increased formability of the various methods of high-energy forming over more conventional methods. For example, extreme elongations of 3 : 1 have been reported for explosive forming, as compared with conventional tensile elongation tests, and it is true that sheet metal can generally be formed considerably beyond the elongations given for incipient necking in a tensile specimen, owing to the unstable condition favouring necking on a tensile specimen. Nevertheless, it may be said that, while some slight increases can be obtained in the total true strain to fracture for a few materials, these are the exception, the general rule being a decrease in elongation when forming materials at high velocities, i.e., in explosive forming. In the case of high-temperature methods of forming, elongation values can be increased by as much as 6:1, owing to the fact that ductility increases considerably with temperature, as has already been indicated.

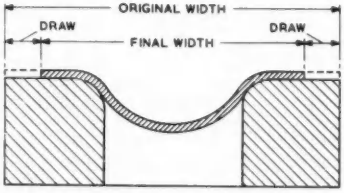

Fig. 15. Drawing action accompanying explosive forming.

One of the confusing aspects of interpreting strain behaviour in explosive forming is the drawing action accompanying forming, as shown in Fig. 15. This drawing action can give the appearance of increased elongation if the drawing-in from the outside edges is not accounted for by subtracting it from the overall change in length when computing strains.

Buckling is a limitation whenever thin-gauge materials are formed and drawing results. The drawing action almost invariably places some of the outer fibres of the material in compression and, if there is an insufficient normal pressure acting on the part, it will buckle into well-defined wrinkles. When forming such parts as beaded panels, shrouds, dome ends, and bulkheads, wrinkles will usually form along the periphery, though wrinkling can be minimized with the aid of pressure plates, as shown in Fig. 16, these pressure plates being actuated mechanically or from the pressure-forming medium itself. However, optimum results are obtained with a pressure medium which is separate from the forming medium, as better control can be achieved.

Spring-back can be minimized either by elevated-temperature creep forming, as in high-temperature methods, or by the use of very high pressures, as in high-

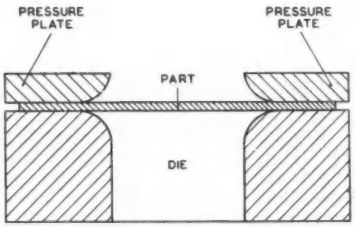

Fig. 16. Method of minimizing wrinkling by means of pressure plates.

velocity methods. In elevated-temperature creep forming, the temperature must generally be of the order of from 400° to 500° F higher than the service temperature of the material being formed, the temperature and forming duration being dependent on the susceptibility of the alloy to creep forming. In high-velocity methods, the pressures must usually be at least 50% higher than the compressive flow stress of the material in order to achieve appreciable spring-back removal. As a guide, the approximate temperatures and pressures necessary to remove spring-back when forming some representative alloys by high-temperature and high-velocity methods are shown in the accompanying table.

Alloy	Creep-Forming Temperature [° F]	Explosive-Forming Pressure [psi]
Magnesium	500	50,000
Aluminium	600	75,000
Titanium	1000	175,000
Stainless steel	1200	200,000
Tool steel	1500	175,000
Beryllium	1500	125,000
Molybdenum	2500–3000	175,000

It should be noted that most of the low explosives utilizing water as the forming medium are ineffective in reducing spring-back. Also, the creep-forming temperatures given in the table are limited by metallurgical factors such as over-ageing, recrystallization, and grain

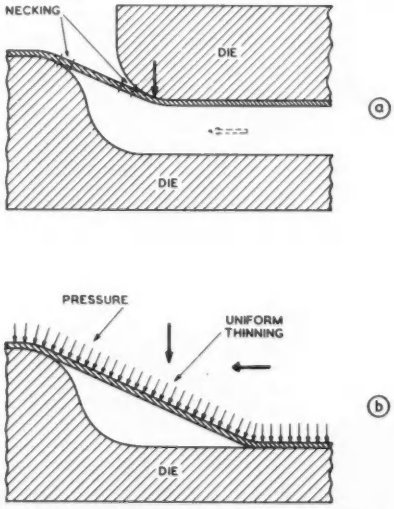

Fig. 17. Distribution of forces when forming a bead (a) with metal dies, and (b) using a fluid as the forming medium.

growth; however, because of the short forming duration at the temperature concerned, this is not as serious a problem as might at first appear.

Uniformity of cross-section is generally improved when using fluids such as water, air, or hot metals as the forming medium, owing to the great reduction in friction, as shown in Fig. 17. Thus, when forming a bead with metal dies (Fig. 17a), only a vertical force is obtained, resulting in necking in the areas shown. This necking will always occur immediately adjacent to the tangent of the forming radii and will ultimately lead to failure. In this case, the horizontal force (shown dotted in Fig. 17a) required to pull the material out of the flat is absent. On the other hand, when using a fluid as the forming medium (Fig. 17b), both horizontal and vertical forces are obtained, giving rise to a more stable condition and hence more uniform thinning, though necking can occur with high-velocity and hot-fluid methods of forming after a critical amount of elongation has been obtained.

As has already been mentioned, the application of materials to high-energy methods of forming is based on such factors as toughness, creep susceptibility, atomic structure, mechanism of flow, and type of fracture. Each material naturally has its own peculiar properties, but there are a number of general factors which can be established to determine formability trends. The application of various materials to the different high-energy methods of forming, from the viewpoint of formability, is given in the following table, in which "A" signifies very good formability, "B" medium formability, "C" poor formability, and "D" unsuitability for forming operations.

Material	Large-Mass Methods	High-Velocity Methods	High-Temperature Methods
Magnesium alloys	C	D	C
Aluminium alloys	B	B	A
Titanium alloys	B	B	A
Stainless steels	A	A	A
Tool steels	B	B	A
Beryllium	D	D	B
Super-alloys	B	C	A
Refractory metals	C	D	B

It will be noted from this table that aluminium alloys, titanium alloys, stainless steels, and tool steels exhibit fairly good formability with all high-energy forming methods. However, beryllium, the super-alloys (nickel and cobalt base), and the refractory metals can be formed satisfactorily only by high-temperature methods, while magnesium alloys do not lend themselves to high-velocity methods and exhibit only poor formability with large-mass and high-temperature methods.

Because of the direction of pressures and limitations in handling these pressures, high-energy methods of forming are limited to specific shapes, as shown in the following table, in which "A" signifies very good applicability, "B" fair applicability, "C" slight applicability, and "D" complete lack of applicability. It should also be noted that the 360 deg. skins mentioned in the table refer to such parts as ducts, shrouds, etc., while skins of less than 360 deg. refer to beaded panels, corrugations, etc.

From this table, it can be seen that only the large-mass methods are suitable for forming flanged stiffeners, because of the difficulty in restraining the pressure medium from getting to the opposite side of the flange. These types of parts could be fabricated by explosive and hot-fluid forming, but extra material would have to be allowed, in order to accomplish proper sealing. This, however, requires a final trimming operation and results in a waste of material.

Type of Part	Large-Mass Methods	High-Velocity Methods	High-Temperature Methods
Flanged stiffeners	B	C	C
Deep-drawn components	C	C	A
Expanded tubes	D	A	B
360° skins	D	B	B
Skins of less than 360°	C	B	A
Sizing	C	A	A

The high-velocity methods can be seen to be applicable primarily to expanded-tubing and sizing operations. Integrally stiffened skins, such as beaded panels, ducts, and shrouds, can be formed readily by these methods, provided that proper sealing methods are used. Deep-drawn parts are generally not very formable by high-velocity methods, except such parts as dome ends and nose cones made of relatively heavy-gauge material and with sufficient lateral support around the periphery to prevent wrinkling.

The high-temperature methods are very applicable to all types of part listed, except flanged stiffeners. Deep-drawing is particularly applicable because the temperature throughout the system can be controlled very well. It is beneficial, for example, to heat the flange to a higher temperature than the remainder of the part, to allow compressive flow and still to retain a high enough strength in the high-tension area for drawing. Practically all integrally stiffened skins are more applicable to high-temperature methods than to the other methods.

Conclusion

Considerable progress has been made in developing high-energy methods of forming, particularly explosive forming, and future work should be directed towards better applications, with a realization of the restrictions and limitations of each method. Thus, when they can be applied, hot-fluid and explosive forming methods eliminate the need for heavy presses, but it must be appreciated that there are numerous types of components and materials which can be formed better with presses. However, it is probable that heavy presses will not be used in the future as much as they are at present on such materials as the refractory metals, beryllium, and some of the super-alloys, as these types of material are likely to be very applicable to high-temperature forming.

The future will see more of explosive forming, particularly in the aircraft industry, where there is a general trend towards aircraft types intended for limited production, so that dies can be made of very thick castings, generally from some cheap and workable material, eliminating the need for excessive machining, etc. However, because explosive forming is most applicable to low production rates, it will probably never become a very good high-production method. On the other hand, high-temperature methods are readily adaptable to fairly high production rates, their principal limitation being the heat loss incurred during changes of parts, resulting in cooling of the die and the need for a rapid heat input to compensate this heat loss. Where forming is feasible by hot-fluid and explosive methods, tooling will become cheaper than with such methods as drop-hammer forming or forming with integrally heated dies.

The Control of Bar-Stock Whip

By B. H. AMSTEAD
From *The Tool Engineer*, U.S.A.,
Vol. 44, No. 5, May 1960,
pp. 89-92, 5 illustrations.

THE higher machining speeds made possible by carbide and ceramic tools are imposing unprecedented demands on both machine tools and bar stock and, although machine-tool problems created by these high speeds are being solved by making the machines more rigid, with a greater mass and larger bearing areas, the problem of bar-stock whip is less easily solved. The use of higher machining speeds causes longer lengths of bar stock to be employed, so as to reduce handling time in the machining cycle and, as either length or rotational speed is increased, so too is the tendency towards bar-stock whip.

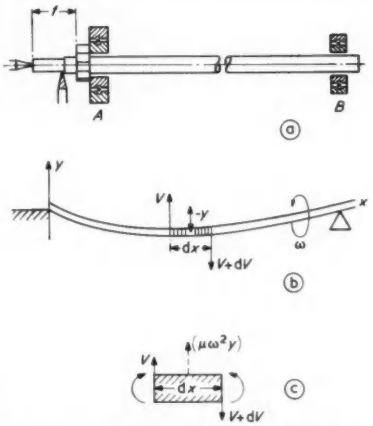

Fig. 1. Schematic arrangement of a typical method of holding bar stock for screw-machine operations and the forces acting on a rotating shaft element.

The causes of bar-stock whip, although they are not easily controlled, are known. A typical method of holding bar stock for screw-machine operations is shown in Fig. 1a, in which *A* is a positive chucking device and *B* a bearing supporting the shaft. The distance *f* is usually short, and the cutting-tool forces contribute only slightly to shaft vibration between *A* and *B*. The shaft centre-line between *A* and *B* does not coincide perfectly with the axis of rotation, because the shaft lacks uniform mass and straightness. Deflection occurs and is increased by centrifugal force and, as the speed of the shaft increases, the centrifugal forces may exceed the elastic forces, in which case the shaft (or the machine itself) will fail. The speed at which instability occurs is the critical speed, which is often designated bar-stock whip or "whirling stock". The forces involved are tremendous, and the danger to personnel and machines is great.

When the speed is further increased past the critical speed, a gradual return to stability results if sufficient forces are brought into play to restrict the movement at the critical speed or if the critical speed is passed over rapidly. Once the first critical speed is passed, however, the next critical speed of the shaft, a harmonic, will be reached as speed is increased.

There is an infinite number of equations defining a shaft rotating as shown in Fig. 1a. With the chuck end of the shaft rigidly held and the other end held in a bearing or simply supported, the following derivation applies :—

When a shaft, rotating at an angular speed ω, is deflected by an amount *y* as the result of the unbalance of centrifugal and elastic forces, the shear is *V* and $(V + dV)$ across an element d*x*, as shown in Fig. 1b. The differential element of the shaft through an element d*x*, measured along its length, has a number of forces acting on it, as indicated in Fig. 1c, and summation of the forces gives

$$-dV = \mu\omega^2 (-y)\, dx \quad .. \quad .. \quad .. \quad (1)$$

where *V* is the shear [lb], *x* is the distance from the rigid end [in.], *y* is the deflection at the distance *x* [in.], and μ is the mass per unit of length. Shear *V* can be defined as

$$V = dM/dx \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

where *M* is the bending moment [lb-in.]. However, from the general elastic curve equation,

$$M = EI\frac{d^2y}{dx^2} = EIy'' \quad .. \quad .. \quad .. \quad .. \quad (3)$$

where *E* is the modulus of elasticity of the material [psi], and *I* is the moment of inertia of the cross-section of the beam about the neutral axis [in.⁴].

Substitution of eq. (3) in eqs. (2) and (1) gives

$$EIy'''' - \mu\omega^2 y = 0 \quad .. \quad .. \quad .. \quad .. \quad (4)$$

$$y'''' - \beta^4 y = 0 \quad .. \quad .. \quad .. \quad .. \quad (5)$$

where $\beta^4 = \mu\omega^2/EI$. Eq. (5) can be solved for ω by substituting values of length and diameter for material with a known modulus of elasticity *E*. Other types of supports can be treated mathematically in a similar manner.

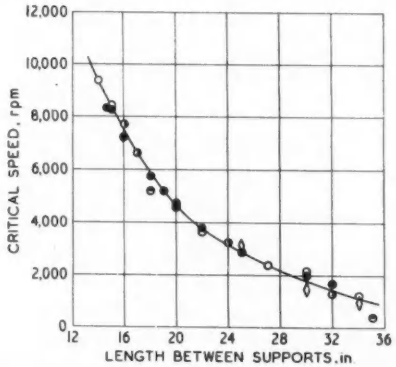

Fig. 2. Fundamental critical speed as a function of the length between supports for a ¼-in. shaft, showing experimental results (solid dots) and theoretical results (open dots).

The successive critical speeds of a shaft are harmonics of the fundamental or first critical speed and are defined as second-harmonics, third-harmonics, etc. Based on mathematical calculations, values of critical speeds, from fundamental up to and including the fifth-harmonic, have been compiled by the author for various sizes of

(*Concluded on page 96*)

The Gyroscopic Mass Flowmeter

By M. M. DECKER

From *Control Engineering*, U.S.A.,
Vol. 7, No. 5, May 1960,
pp. 139–140, 5 illustrations.

THE ability to measure true mass flow, rather than volume flow, is becoming more and more necessary with more stringent quality-control requirements in certain industries where there is a natural need for mass-flow data, e.g., in the case of chemical reactions, which are essentially mass reactions.

In this connection, a mass flowmeter of exceptional accuracy and versatility, based on the gyroscopic principle, has been designed. If a section of tubing carrying a flowing fluid is bent into a circular loop, the total angular momentum of the fluid in the loop is proportional to the mass flow rate. Gyroscopic action is a response to total angular momentum, and it therefore follows from gyroscopic-precession relationships that, if a fluid-carrying loop is suspended vertically and vibrated about its vertical diameter (the angular momentum being about an axis normal to the plane of the loop), a precession torque will appear about the horizontal diameter of the loop, having the same frequency as the input vibration and an amplitude proportional to the mass-flow rate of the fluid in the loop. An instrument of this type will measure the mass flow of almost anything passed through it, such as non-Newtonian fluids, slurries, solids in gases, etc.

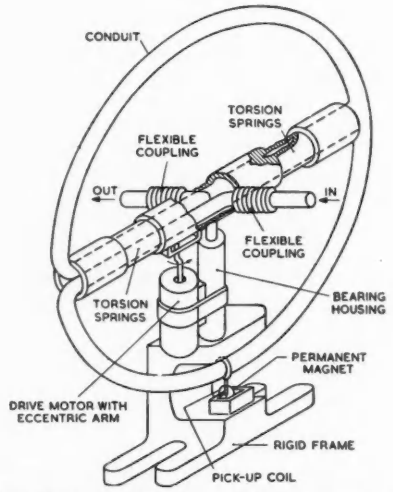

Fig. 1. Schematic arrangement of an early form of gyroscopic mass flowmeter.

Fig. 1 shows an early form of the vibrating gyroscopic flowmeter. The centre of the loop is the mechanical centre of the instrument, which is connected to the external pipeline through two flexible couplings. The fluid makes two right-angle bends when entering, a 360-deg. rotation, and two right-angle bends when leaving. Since no orifices, vanes, or plugs obstruct the stream, the pressure drop is due only to these bends and the flexible couplings, and can normally be made negligible.

The radial pipe sections are freely surrounded by a hollow shaft which forms the horizontal diameter of the loop. The only connection between this shaft and the radial conduits is made at the left end of the horizontal axis where the conduits join the loop. Two reduced sections of the horizontal shaft act as torsion springs to permit vibration about the horizontal axis.

The vertical shaft is rigidly connected to the horizontal shaft at the centre and is bearing-mounted, so that the whole instrument assembly can rotate about the vertical axis. A constant-speed motor drives the loop through a slot-and-eccentric-pin linkage, and can be quite small, since only reactive power is required, except for the bearing losses. The amplitude of the input oscillation is adjusted by the eccentricity of the driving pin. The frequency is determined by the speed of the exciter motor.

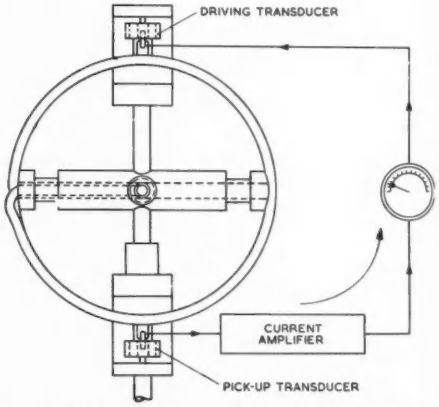

Fig. 2. Modified gyroscopic mass flowmeter with torque feedback loop to eliminate resonance.

Besides being proportional to mass rate of flow dM/dt, the output amplitude θ is also a function of input amplitude φ and frequency ω, both of which must therefore be held constant. The moment of inertia I_x about the X axis resonates with the spring constant k_x about the horizontal axis at a frequency $\Omega_x = (k_x/I_x)^{\frac{1}{2}}$. Since the moment of inertia of the loop includes the total mass of the fluid in the loop, this resonance frequency depends on the density of the fluid.

Fig. 2 shows a system which is similar to that in Fig. 1, except for the addition of a torque feedback loop to eliminate the resonance and thus the sensitivity to density. The constant-velocity input drive is replaced with a constant-torque drive, so that, in this case without feedback, the input angle φ would vary with frequency, but the torque would be independent of frequency. The voltage generated in a pick-up transducer mounted at the bottom of the loop is amplified, and the amplifier output drives a second coil diametrically opposite the pick-up. The output is phase-sensitive relative to the input frequency, going through a 180-deg. shift at zero mass flow, so that the gyroscopic mass flowmeter will measure reverse flow. Phasing is arranged so that the torque produced by the

feed-back coil opposes the torque caused by the gyroscopic action of the flowmeter, reducing the amplitude of the output vibration considerably.

The magnitude of the amplifier output current in Fig. 2 is directly proportional to mass-flow rate. The high negative feedback results in an effectively non-resonant system that permits a high drive frequency and thus a low response time. The constant of proportionality depends only on basic instrument-design parameters and is not affected by age, temperature, pressure, line voltage, viscosity, density, etc. Consequently, the calibration of the flowmeter is very stable. The current which drives the feedback transducer can be integrated by electrical circuits, watt-hour meters, or many other devices to indicate or record total mass flow.

The prototype flowmeter has been refined mechanically to reduce its sensitivity to external accelerations, and has a full-scale rating of 500 lb/min, using a 1½-in. stainless-steel conduit with a loop diameter of 12 in. The horizontal resonance frequency is 100 cps, the drive frequency is 12 cps, the drive amplitude is 0·20 deg., and the full-scale output displacement is 0·0015 deg. without torque feedback. An electronic console indicates flow rate and totalized flow rate digitally to better than ±1% of full scale and includes constants for actuating process controllers when the total flow or flow rate reaches a preset value. Telemetering transmitters can be added for transmitting data to a remote point.

In a series of 79 tests carried out by the Armour Research Foundation, an early crude type of gyroscopic mass flowmeter showed an error of 0·45% r.m.s. of full-scale reading. The results of 108 test runs (54 each of plus and minus flow) made more recently by The Decker Corporation on the production model, using flow rates between 20 and 500 lb/min, showed an accuracy within 0·5% of full-scale reading.

The Effects of Welded or Sprayed Metal Deposits on the Fatigue Strength of Shafts

By K. WELLINGER and P. GIMMEL

From *Werkstattstechnik*, Germany,
Vol. 50, No. 5, May 1960,
pp. 269-273, 14 illustrations.

METAL deposition by welding is frequently used for repairing the worn bearing surfaces of rotating shafts and, more recently, metal spraying has also been adopted as a means of building up such shafts to their original size. It has, however, long been known that, because of continuously recurring service failures of parts repaired by welding, low and steady operating loads are an essential requirement for parts repaired in this way, and various precautionary measures and restrictions have been put forward, as it has long been recognized that metal deposition by welding can cause a marked reduction in the durability of mechanical components.

Fatigue tests carried out by the authors some years ago* have shown that shafts with weld-deposited metal have a considerably lower fatigue strength than shafts consisting entirely of the original material. Thus, caution seems advisable, particularly with high fatigue loads, with high stress concentrations (notch effects), or with shafts made of materials with a high ultimate tensile strength. For instance, comparative tests on shafts of a 45-kg/mm² steel, 60 mm in diameter, reported in this particular investigation, showed that deposition of weld metal reduced the fatigue strength of these shafts from its original value of 23 kg/mm² to as low as 5 kg/mm².

At the same time, it should be appreciated that there are many workpieces repaired by deposition welding which have proved successful under suitable conditions. For this reason, the authors decided to carry out further tests and also to investigate the effect of stress-relief annealing on a number of welded shafts, as it is known that this treatment reduces residual stresses, which can be fairly high, particularly in thick cross-sections. Moreover, as metal spraying offers further possibilities, shafts treated by this process were similarly tested.

The specimens used for these tests consisted of rolled cylindrical bars of a 50-kg/mm² steel, 60 mm in diameter,

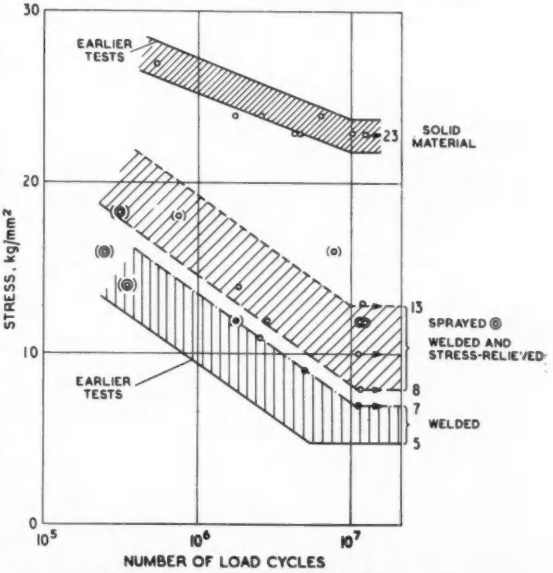

Fig. 1. Wöhler curves for steel shafts of 45 mm diameter, showing results for the original solid material and for shafts subjected to different deposition treatments, i.e., by metal spraying and by welding, with and without stress-relief annealing.

* K. WELLINGER and P. GIMMEL: *Das Industrieblatt*, No. 1, 1952.

and about 2 m in length between bearings. Test sections in these bars, about 300 mm in length and machined to diameters varying from 44 to 50 mm, were subjected to different deposition treatments, i.e., by metal spraying and by welding, with and without stress-relief annealing. In the case of metal spraying, the surface was suitably roughened before spraying.

The results obtained with a test section of 45 mm diameter are shown graphically in Fig. 1, from which it will be seen that, for specimens built up by welding and not subsequently stress-relieved, there is a drop in fatigue strength from the original 23 kg/mm² to 7 kg/mm² —a result which is substantially in agreement with the results of the earlier tests. Stress-relief annealing of the rebuilt testpieces shows an increased value of fatigue strength, i.e., between 8 and 13 kg/mm², while the fatigue strength of the sprayed shafts is about 12 kg/mm², these treatments therefore increasing endurance by about 50%. At high loads, the test points of the sprayed shafts are within the region of scatter of the welded specimens. It should also be noted that polishing of the treated specimens afforded no noticeable advantages, compared with the ordinary surface finish obtained by machining, at least in the case of specimens of the sizes and types used in these tests.

The fractured surfaces of the specimens rebuilt by welding showed that the fractures had their origin in pores on or under the surface, whereas fracture of the sprayed specimens originated at the surface of the metal where it had been roughened to secure adhesion of the sprayed metal, the sprayed-on layer breaking off obliquely on both sides of the fractured area. In this connection, it should be noted that, apart from the possible effects of spraying, the load-carrying capacity was reduced by the terminations of the helical grooves constituting the roughened area in the base metal.

These fatigue tests were followed by hardness determinations on the surface and also below the surface of the deposited metal for a number of specimens. It was found that the sprayed-metal layers were harder than welded layers with stress-relief annealing, the hardness of the welded and stress-relieved layers being uniform and only slightly greater than that of the base metal. This uniformity contributes to the relatively high fatigue-strength values obtainable, but it should be borne in mind that shafts built up with deposited metal have a reduced load-carrying capacity, so that the avoidance of severe dynamic loading conditions is recommended.

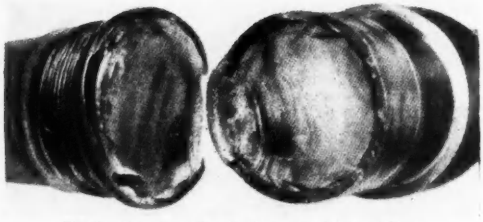

Fig. 2. Fracture of a shaft repaired by welding.

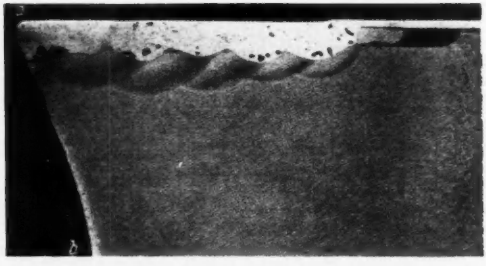

Fig. 3. Cross-section through part of the fractured area of the shaft shown in Fig. 2, after polishing and etching.

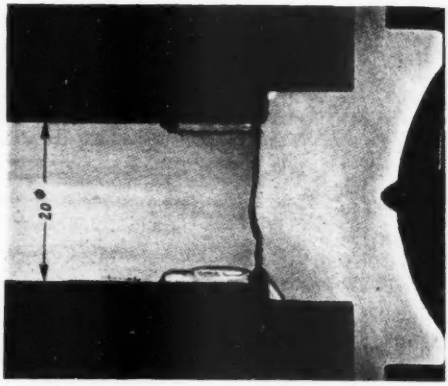

Fig. 4. Cross-section through the fractured area of the flanged shaft of a motor roller, repaired by metal spraying.

An example of shaft failure is provided by the case of a worn shaft, 80 mm in diameter, which was repaired by welding and then machined down to the required size, after which it was provided with a bush for use with a ball bearing, instead of a plain bearing. After many years, a fracture occurred at the end of the welded region, originating in the weld metal. A fatigue fracture then developed in the shaft material, resulting in sudden failure of the residual cross-section (Fig. 2). The weld material was found to be very porous, and the transition region very marked, as shown in Fig. 3, which is a cross-section of part of the fractured area after polishing and etching. This failure was due to bending and shows that shaft fractures can occur after long periods if the working stress is not constant but fluctuates between maximum and minimum values during a sufficiently large number of load cycles.

Service failures have also occurred with sprayed-metal shafts subjected to alternating stresses. Thus, as an example, the flanged shaft of a motor roller, repaired by metal spraying, fractured at the end of the sprayed-on layer soon after reconditioning (Fig. 4). In this connection, the trouble that can be caused by such failures in motor vehicles should be mentioned, though it is true that firms advocating the sprayed-metal process always indicate the limits of of applicability.

Among recommendations referred to in the literature, the following should be noted :—

(1) Parts that are worn and that require additional strength are not suitable for metal spraying.

(2) The metal-spraying process should be carried out by specially trained personnel and in suitably equipped workshops, in strict accordance with recommendations concerning process conditions.

(3) As in the case of parts built up by welding, spraying is not advisable in doubtful cases, such as those associated with high dynamic loads or where the stress conditions are unfavourably affected (e.g., by excessive weakening of the shaft) as a result of preparatory work.

An Automatic Dew-Point Hygrometer using Peltier Cooling

By P. GERTHSEN, J. A. A. GILSING, and M. VAN TOL

From *Philips Technical Review*, Netherlands,
Vol. 21, No. 7, 1959/60,
pp. 196-200, 5 illustrations.

DETERMINATION of the dew-point is the most accurate method available for measuring the humidity of air or other gases and is generally superior to other methods. Thus, such instruments as hair hygrometers are dependent on material properties and therefore require regular calibration, while electrolytic methods and wet-and-dry bulb methods are liable to error because of the presence of dirt.

It is true that a complication of the dew-point method is the need for cooling, in order to reach the dew-point, and it is for this reason that this method has hitherto been used only in laboratories and has not been adapted to industrial applications. Now, however, this objection has been overcome by the availability of semiconductors which make it possible to provide by very simple means a method of electrical cooling, based on the use of the Peltier effect, which occurs when an electric current is passed through a circuit of two conductors of dissimilar materials connected in series, heat being generated at one junction and absorbed at the other. The amounts of heat absorbed or developed per unit of time are proportional to the current, the proportionality factor being the Peltier coefficient P of the particular combination of conducting materials. If the situation is reversed, i.e., if the circuit is opened and the junctions are brought to different temperatures, there appears across the terminals of the thermocouple so produced a potential difference that depends on the temperature of each of the junctions.

Based on the use of the Peltier effect, automatic equipment for determining the dew-point has recently been developed by Philips and utilizes the principle of a change from specular to diffuse reflection caused by the misting-over of a reflector. As such, it is a variant of similar equipment previously developed by Philips, based on the same principle, but using liquid air to effect the necessary cooling, instead of the Peltier effect.

The new dew-point hygrometer using the Peltier effect is shown schematically in Fig. 1, in which two blocks (1) and (2), made of different semiconducting materials, are joined at positions *a* by a silver plate (3), about 5 mm in thickness and width and about 15 mm in length. At positions *b*, these blocks are connected to fairly large and thick copper plates (4) which act as "cooling fins" and which also serve to conduct current to the blocks, the components (1), (2), (3), and (4) constituting the whole Peltier element, as shown in Fig. 2. The upper surface of the silver plate (3) is polished so as to produce a plane mirror, onto which is directed at an angle of approximately 45 deg. a parallel beam of light, derived from an electric lamp and a lens, the reflected beam impinging on a small photoresistor of cadmium sulphide (5), as shown in Fig. 1.

When the equipment is switched on, so that current flows through the blocks and the reflector in the right direction, heat is developed at the junctions *b* and withdrawn from the junctions *a*. As soon as the temperature of the silver plate (3) drops below the dew-point, the surface of the strip mists over and ceases to reflect specularly. The incident light is now reflected diffusely, and less light reaches the photoresistor. As a result, the current flowing through this resistor also decreases. By means of an appropriate circuit *A*, the photocurrent controls the current flowing through the Peltier element in such a way that the cooling diminishes when the reflector mists over. The entire system thus constitutes a closed control loop. The temperature of the silver plate then rises once more above the dew-point, the mist disappears, and the process repeats itself. Effective damping of the control loop is ensured by suitably selecting the time constants, so that the equilibrium temperature or dew-point is reached after only one or two oscillations. In the side of the silver plate (3) are a number of 1-mm holes, into which a thermocouple or thermistor is introduced for measuring the temperature.

It should be added that the diffuseness of reflection of the misted reflector depends on the "thickness" of the layer of condensate. This thickness, which can be expressed as the quantity of water per unit area of reflector surface, is proportional to the difference between the temperature of the reflector and the dew-point and is also proportional to the time. After the temperature has dropped below the dew-point, the nett cooling decreases, but does not become negative immediately. The control is not an on-off control but a proportional control, and the "integration" of dew on the mirror gives the system a measure of integral action.

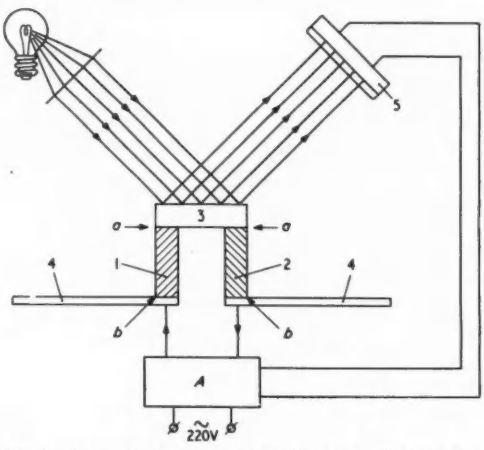

Fig. 1. Schematic arrangement of the automatic dew-point hygrometer.

The fact that the equilibrium temperature coincides with the dew-point and cannot be below it can be understood by considering that, if the temperature of the reflector, and hence of the water condensed on its surface, is below the dew-point, the mist will become increasingly dense and the cooling will decrease. Only when this

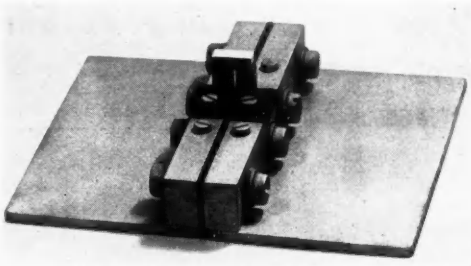

Fig. 2. Complete Peltier element.

temperature rises to the dew-point can the mist achieve a steady state and the cooling remain constant.

With regard to the circuit *A* in Fig. 1, it should be noted that, since the resistance of the Peltier element is low, though the current through it is fairly high (as much as 7 amperes), the simplest method of obtaining this current is to use an a.c. mains supply transformed down to a low voltage and then rectified. The primary of a transformer is connected via a transductor (saturable reactor) to the secondary of a mains transformer, direct current being obtained by means of two germanium diodes and smoothed by a choke. The control current flowing through the saturable reactor is varied by a photoresistor with the aid of a transistor.

It should be noted that there is a limit to the temperature depression attainable with a Peltier element. True, the temperature depression produced is proportional to the current flowing through the element, but, on the other hand, ohmic heat is also generated, which increases in proportion to the square of the current. There is thus always a certain current at which the ohmic heating exactly compensates the Peltier cooling. Furthermore, there is also heat transfer from the warm to the cold junction via the Peltier elements themselves.

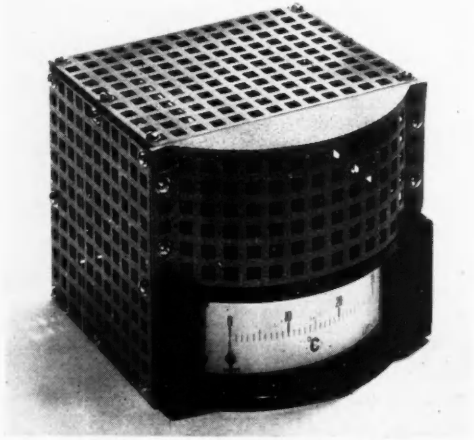

Fig. 3. View of complete instrument.

A particular large value of the Peltier coefficient *P* can be obtained by combining an *n*-conductor and a *p*-conductor. Of the two materials used in this particular instrument, one consists of about 80% by weight Bi_2Te_3, 20% Bi_2Se_3, and 0·02% AgI (*n*-conductor), and the other about 60% Sb_2Te_3, 40% Bi_2Te_3, and 0·05% Ag (*p*-conductor), these being used in the form of blocks (1) and (2) in Fig. 1, each of which is 9 mm in length and 5 mm in width and thickness. With a current of 3 A, this element gives a temperature drop of about 30°C, the maximum temperature drop being about 45°C with a current of about 7 A.

The complete instrument (Fig. 3) comprises a perforated metal case, which houses the Peltier element, the lens system, the electrical circuit, and a millivoltmeter calibrated in °C in the lower half of the front panel. The copper plates of the Peltier element are mounted vertically, close to the rear wall of the instrument, the space above the millivoltmeter containing the lens system and electrical circuit. The error in dew-point determination with a hygrometer of this type can easily be made less than ½°C.

The Control of Bar-Stock Whip

(*Concluded from page 91*)

round bar stock, ranging from ¼ to 5 in. in diameter, and with distances between supports ranging from 6 in. to 20 ft, using the most common type of support. To check the reliability of these calculations, special experimental equipment has been constructed and the fundamental critical speeds of a ¼-in. shaft have been determined. A comparison of the theoretical and experimental results obtained is given in Fig. 2, which shows the fundamental critical speed of the ¼-in. shaft as a function of the length between the supports, the solid dots indicating the actual speeds and the open dots the theoretical speeds. It can be seen that there is excellent agreement between the theoretical and actual values, despite the fact that no effort was made to select a straight piece of bar or to ensure a definite bearing clearance.

From a practical viewpoint, bar stock should be rotated at a speed which is at least 20% below the fundamental or first critical speed, or at speeds which are considerably greater than the fundamental critical speed. In this connection, it should be noted that, although it is difficult to damp the first critical speed encountered in bringing bar stock up to an elevated speed, the forces causing the whip do not have time to develop if this critical speed is passed through with sufficient rapidity, and, in any case, higher harmonics are far less detrimental than the first critical speed. Consequently, machines with high accelerations are preferable if bar stock is to be rotated at post-critical speeds.

The only economical method of raising the critical speeds of a given bar is to put it in tension, as compression lowers the critical speed and encourages buckling. For instance, tests carried out on a ¼-in. bar show that the critical speed is materially increased by applying even small amounts of tension, critical speed varying almost linearly with tension, with values ranging from about 3000 rpm at zero tension to about 4800 rpm at a tension of 1600 psi. In addition, by the application of tension, the amplitude of vibrations is greatly reduced and the damaging fundamental critical speed is passed with less motor torque and reduced vibration. In short, it may be said that a simple thrust bearing held against a collar on the bar stock and pulled to produce sufficient tension is an effective solution to many bar-stock whip problems at high rotational speeds.

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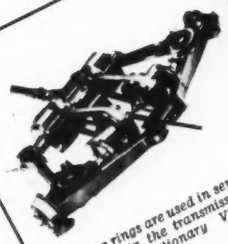

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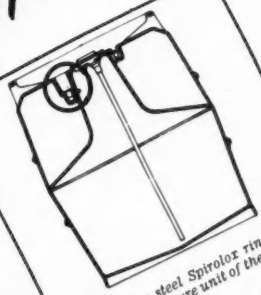

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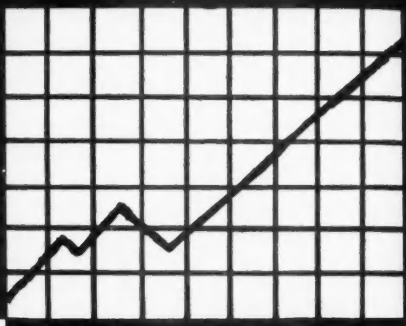

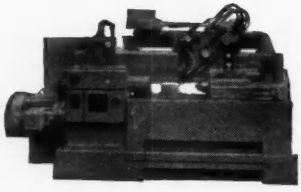

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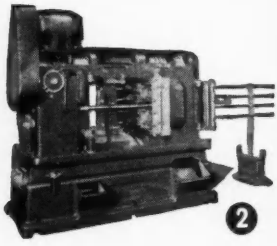

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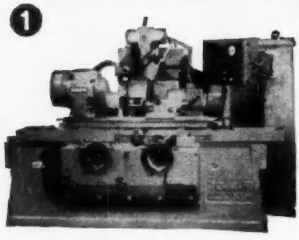

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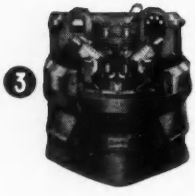

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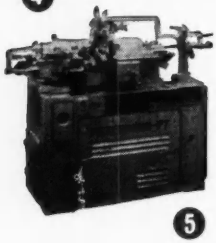

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INTERNATIONAL MACHINE TOOL EXHIBITION, 1960

In our June issue, a preview was included of a representative range of equipment shown at the International Machine Tool Exhibition, which was held this year at Olympia, London, between June 23 and July 8. A further selection of items from this Exhibition is reviewed in the following pages.

Charles Churchill & Company Limited

As is only to be expected, a wide range of equipment was exhibited by Charles Churchill & Company Limited, of South Yardley, Birmingham, including representative examples from such firms as Scharmann & Co. G.m.b.H., of Rheydt, Germany, ("Opticut" machines, including the new FB 500 B machine for precision boring, snout boring, heavy milling, and general diameter facing), from Froriep Ltd., of Rheydt (vertical turret lathes), from S.A. Jos. Petermann, of Moutier, Switzerland (automatics), from Wieck & Hentzen, of Remscheid, Germany ("Supfina" centreless superfinishing machines), and from the Cone Automatic Machine Co. Ltd., of Aldridge, who have achieved the same reputation for the dependability and accuracy of their six-spindle and eight-spindle "Conomatic" automatic machines as their American parent company in Windsor, Vermont. Other exhibits included standard-duty lathes, quality precision centre-lathes, heavy-duty lathes, and profiling lathes made by **Churchill-Redman Ltd.**, of Halifax, a member of the Churchill group, and a Churchill-Curtis conveyor grinder, which successfully achieves a combination of fast metal removal by abrasive belts with automatic feeding. The type 304 C machine exhibited is a smaller version of the type 600 C, and has a capacity for grinding, polishing, and deburring up to 4 in. in width and 2½ in. in thickness, and can be used wet or dry.

Exhibits from **Churchill Gear Machines Ltd.**, a subsidiary of Charles Churchill & Co. Ltd., included a gear-honing machine specially designed to apply the principle of finish-honing gears to remove nicks and burrs and to improve the quality of surface finish, and the Churchill MK IV "Rigidhobber", a standard machine which incorporates electrical and hydraulic features to facilitate the application of semi-automatic and fully automatic loading systems, the machine on show being the model S.815 MK IV, fitted with a standard C.G.M. transfer arm and a continuous rotary-chain conveyor.

Other exhibits from Churchill Gear Machines Ltd. included a model G.R.C. 8-in. gear-tooth chamfering machine, designed to facilitate automatic loading and to accommodate single, compound, or cluster gears, and their C.G.M. 24-in. universal gear hobber, presented for the first time. The model on show can accept a maximum gear diameter of 26 in., but an alternative machine can be offered to accept gears up to 36 in. in diameter. The vertical traverse on the hob slide is 15 in., the maximum diametral pitch is 3, the minimum number of teeth which can be cut is 8, and the machine will accept hobs of 7 in. maximum diameter and 7 in. maximum length. The machine is equipped with infinitely variable feed and speed mechanisms, controlled through P.I.V. units, giving vertical feed rates between 0·010 and 0·290 in. and speeds between 65 and 300 rpm. An arrangement for automatic feed change at full depth is also provided.

In addition, Churchill Gear Machines Ltd. exhibited two models from a new range of gear-shaving machines, with entirely new operational features, especially developed to improve reliability, repetitive accuracy, ease of set-up, and accessibility. One of the models exhibited is the S.A.U. 8-in. semi-automatic universal gear-shaving machine, which is equipped with the new and exclusive C.G.M. micro-positive auto-electric knee and table, and a hydraulically operated tailstock. With this arrangement, all that is necessary for the operator is to place the component on its arbor, in mesh with the gear-shaving cutter, on an approximate locator, before closing the guard door and operating the machine-cycle start-button. The automatic tailstock then comes forward to locate the component between centres, and the shaving cycle commences.

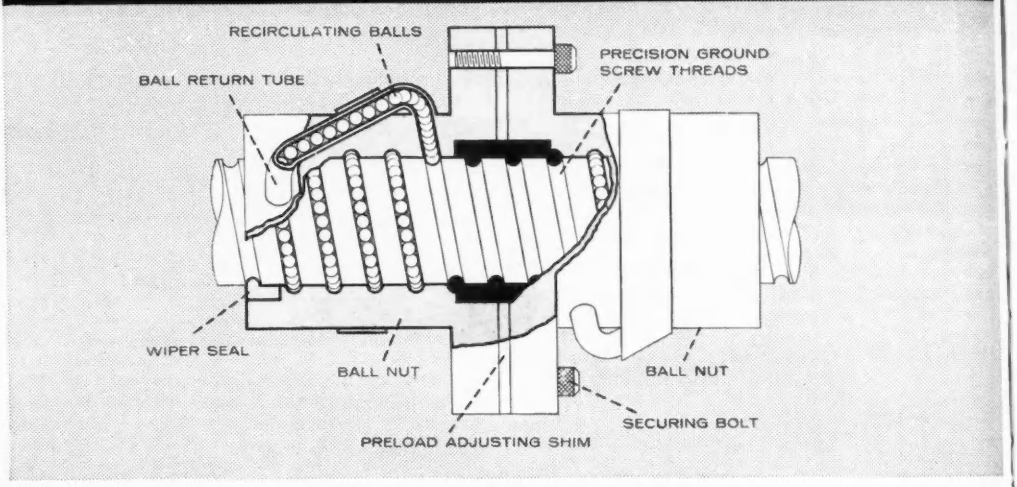
The other gear-shaving machine exhibited is the model F.A.U. 8-in. in-line fully automatic universal machine. This model also incorporates the micro-positive auto-electric knee and table and automatic hydraulic tailstock but, in addition, a standard C.G.M. auto-loader of well-known and proved design and a conveyor system are utilized. The auto-loader incorporates a hydraulic-piston arrangement for transferring the components from the pick-up to the cutting and ejection points between the load and to the unload conveyors.

Kendall & Gent Limited

In addition to a range of broaching machines, portable radial drilling machines, screwing machines and tangential cutters for screwing machines, face-milling cutter grinding machines, and milling cutters, Kendall & Gent Limited, of Gorton, Manchester, exhibited a range of milling machines, including their electronically controlled plano-milling machine, which features electronically controlled infinitely variable table and milling-head feeds, automatic spindle retraction, semi-cycle control of table traverse, and "steering" control to the table and milling-head traverses.

This machine, which has a capacity of 20 × 6 × 6 ft has three milling heads, i.e., one vertical head on the cross-slide and two horizontal heads (one on each upright), as shown in Fig. 23. Each milling head is powered by its own 30-hp motor mounted directly on the head, providing a short and rigid transmission. The spindles have sixteen changes of speed in the range between 12 and 780 rpm. The spindle power traverse can be operated from a pendant control station or a control panel on the milling head. The traverse controls are interlocked in such a way that it is impossible to traverse the spindle while in the locked position. The

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



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Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

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drive for the milling-head traverses is from a 15-hp d.c. variable-speed motor which provides infinitely variable feeds from 1½ to 45 ipm, as well as a rapid traverse of 75 ipm. Selection of feed or rapid traverse is made by means of a rotary switch on the pendant, while selection of the particular feed required is obtained from a graduated potentiometer, also on the pendant. The precise feed selected is indicated on a large-diameter tachometer on the floor-mounted control desk. Table traverses, similar to those for the milling heads, are derived from a 15-hp d.c. variable-speed motor which provides infinitely variable feeds between 1½ and 45 ipm, with a rapid traverse of 150 ipm.

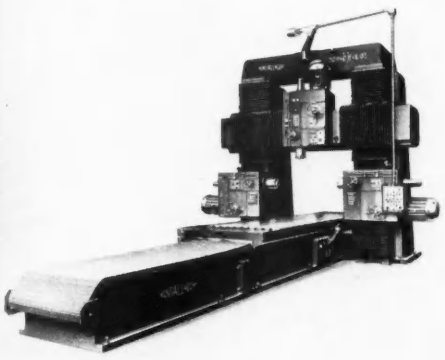


Fig. 23

The final drive to the table is by the well-known Kendall & Gent patented worm and semicircular rack method and incorporates a special hydraulic mechanism designed to eliminate any backlash present in the traverse motion. Both the table and the milling heads are equipped with optical measuring devices, working in conjunction with precision graduated rules, permitting accurate and convenient setting to within 0·001 in.

The spindle-retraction and incremental-feed system allows the operator to retract the cutters clear of the workpiece for rapid-traverse return of the table, and also makes it possible to set the tables for a finishing cut of anything from 0·001 to 0·010 in. Spindle retraction is controlled by a rotary switch on the pendant, and the drive for the retraction and incremental-feed system is so arranged that all the spindles can be operated simultaneously or independently. When it is desired to take a finishing cut, the incremental-feed system can be brought into operation, the controls for the system being carried on the control desk, together with a potentiometer graduated in 0·001 in. for setting the depth of finishing cut required. Provision is also made to operate the table traverse in the form of a semi-cycle to cover workpieces requiring a multiple number of cuts, this being controlled by the same rotary switch as that used for retraction of the spindles. This semi-cycle control system is extremely useful in achieving greater production, as it is accomplished without the operator having to move from his position and without wasting time in making adjustments.

The facility of "steering" control enables a cutter to be guided remotely by the operator around irregular shapes at a constant vector speed. The electronic control equipment is so arranged that, when steering is selected by means of a rotary switch on the control desk, both the table and the milling-head traverse motors are simultaneously controlled, allowing the direction of travel of the cutter in relation to the work to be steered through 360 deg. As a result, the cutter can be guided around an irregular shape, either in a vertical or a horizontal plane, depending on which milling head is selected for operation. The steering controls are mounted on a portable control station plugged in to the main control desk, the feeds for steering being infinitely variable between 3 and 45 ipm.

James Archdale & Co. Ltd.

Of the range of equipment exhibited by James Archdale & Co. Ltd., of Birmingham 16, special interest undoubtedly attaches to their "Autonomic" machine-tool control system, which has been evolved as a result of close co-operation of specialists in different fields, working within the single organization of the Staveley Group of companies, of which Archdale is a member. The system utilizes punched tape, the tape-preparation scheme having been devised to blend in with existing drawing-office and planning-office routines, using commercially available tape-preparation equipment.

The Archdale "Autonomic" 6 ft × 6 ft vertical co-ordinate drilling machine, illustrated in Fig. 24, is an example of the application of this control system, the machine programme including drilling, reaming, tapping, and spot-facing, in conjunction with co-ordinate positioning and automatic speed, feed, and tool change. The machine has a drilling capacity up to 1¾ in. diameter in mild steel, the accuracy of positioning of the table and saddle being ±0·001 in., of the spindle traverse without dead-stop ±0·010 in., and of the spindle traverse with dead-stop for facing ±0·001 in.

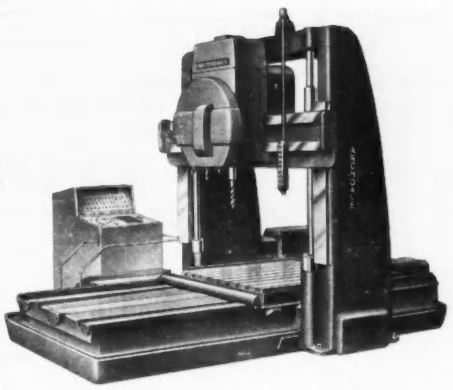
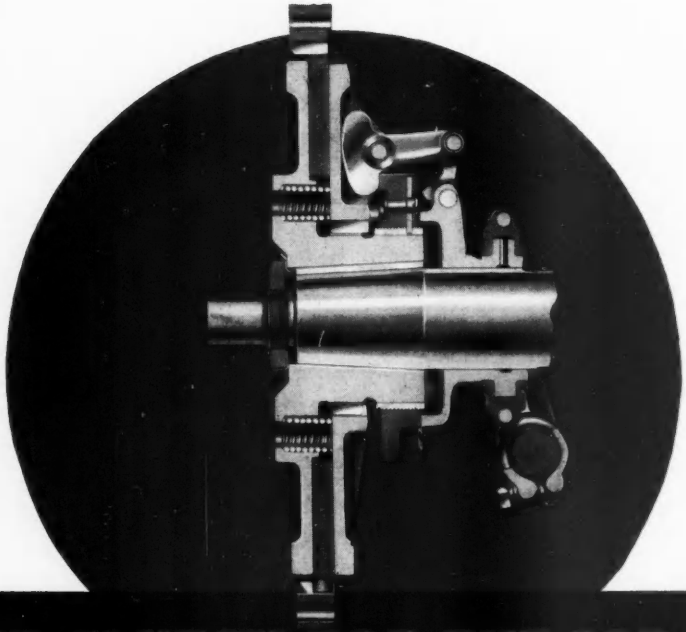


Fig. 24

The tape reader and all controls, indicator lamps, and dials are mounted on a console which houses the control electrical equipment and power-supply units. Pendant controls are provided for use when setting up the machine under manual control. On the console are the push-buttons used when the dimensional data are fed into the machine manually instead of from the tape. Spindle speeds, feeds, and the type of cycle, i.e., drilling, spot-facing, or tapping, are preset by dials for each of fifteen tool numbers. Thus, changes of speed and feed may be



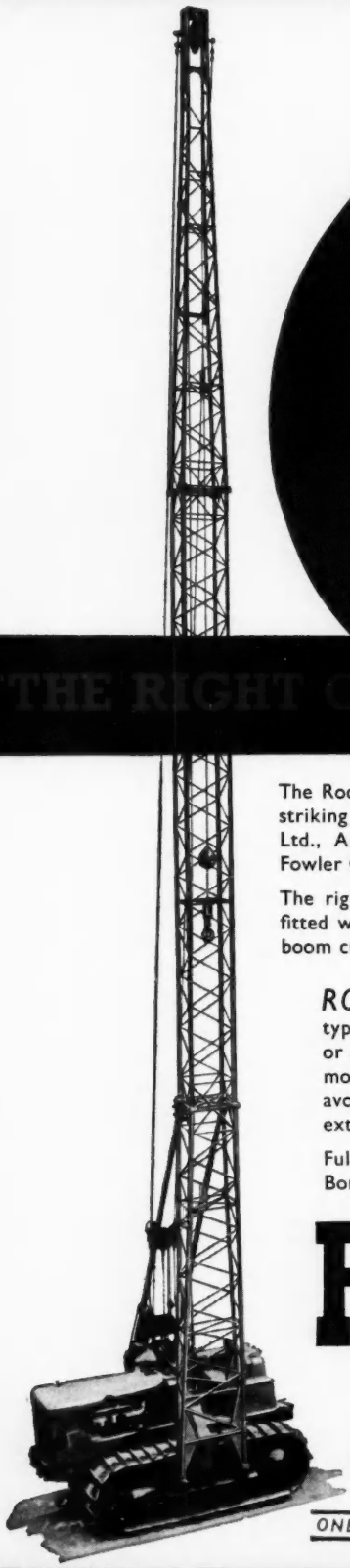
THE RIGHT CLUTCH FOR THE JOB

The Rockford 11½" single plate over-centre clutch unit is used in the striking side boom equipment (left) made by T. T. Boughton & Sons Ltd., Amersham Common, Buckinghamshire, and installed on a Fowler Challenger 33 Tractor.

The right-hand illustration shows a Caterpillar D.8 Tractor, also fitted with an 11½" Rockford clutch unit and T. T. Boughton side-boom crane attachment.

ROCKFORD FEATURES Being an over-centre type, the Rockford clutch is held positively in the engaged or disengaged position; when being operated the thrust is momentary, and in the running position end thrust is avoided. Easily adjusted; easily maintained. Made in an extensive range of sizes etc.

Full particulars on application of Rockford products and Borg & Beck clutches.



ROCKFORD

FRICTION CLUTCHES
POWER TAKE-OFFS

BORG & BECK COMPANY LIMITED
LEAMINGTON SPA, WARWICKSHIRE, ENGLAND

ONE OF THE AUTOMOTIVE PRODUCTS GROUP

effected for any tool without alteration to the tape When a particular tool number is demanded by the tape, the speed and feed preset by the dials will be obtained automatically. There are fifteen rates of both speed and feed. A "mirror-image" switch is provided, so that right- and left-handed components can be produced from the same push-button setting or tape information.

The main operating sequence of the machine is initiated by a "director" switch which, in turn, controls the positioning system and machine cycle. An important feature of this system is the use of interlocks, whereby the sequence of operation cannot continue until the previously demanded movement has been completed. The cause of any failure is then indicated by the position of the "director" switch. Control of the machine can either be fully automatic, semi-automatic, or manual.

Alfred Herbert Ltd.

Quite apart from an extremely wide range of machine tools of various types produced by about twenty different firms, exhibits from Alfred Herbert Ltd., of Coventry, included examples of Herbert/Cri-Dan threading machines, Herbert/DeVlieg "Jigmil" machines, and Herbert/Smallpeice auto-cycle lathes, together with a representative selection of Herbert turret-type drilling machines, surface grinders, milling machines, and lathes.

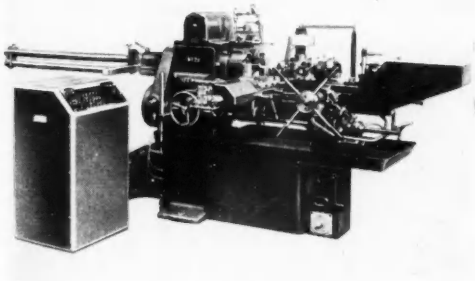


Fig. 25

In addition to a Herbert No. 2D capstan lathe with the Herbert punch-board system of programme control and their "Autobar" chuck, a similar lathe, but with an "Auto-Robot" control system and "Autobar" chuck, was exhibited. This equipment (Fig. 25) is an adaptation of the standard No. 2D capstan lathe for fully automatic high-production repetition bar work up to 1½ in. in diameter, the "Auto-Robot" system automatically controlling every movement of the machine, including the "Autobar" chuck, ensuring, with the weight-operated bar-feed unit, automatic bar feeding to accurate length. Setting the control system involves placing a punched card over a printed circuit, the holes in the card corresponding to the signalling-switch circuits required for a complete work cycle. The signalling-switch circuits are energized via a scanner and actuate air cylinders connected to normally hand-operated machine elements. The control panel is duplicated by a set of hand switches for setting-up purposes, and manual pilot-wheel control to the capstan slide is also retained.

Other Herbert lathes exhibited include a No. 2 "Flashcap" lathe fitted with an air-operated turret-indexing mechanism and other attachments, a No. 90 combination turret lathe with hydraulic copying attachment, a No. 12B cross-sliding turret lathe, a "Carbi-junior" copy-turning lathe, and a No. 4 Senior "Preoptive" capstan lathe with hydraulic copying attachment. This machine (Fig. 26) is intended for chuck work up to 15½ in. swing and bar work up to 2 in. in diameter, the sixteen-speed, power-operated "Preoptive" headstock eliminating idle time resulting from speed changing, as speed selection and change are accomplished without stopping the spindle and while cutting, if necessary.

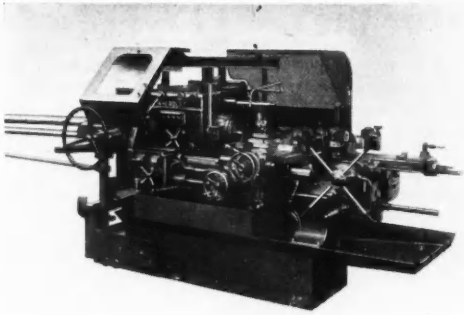


Fig. 26

A new feature of this machine is a hydraulic copying attachment designed to reproduce internal, external, and face profiles on components, using either a template or a model. The copy-turning tools are carried in easily detachable, accurately repositioned toolposts, and the change from roughing to finishing tools can be accomplished quickly. Several types of toolholder are available, including straight and angular holders for shank-type tools and clamped-tip and boring-bar holders, the latter for internal work. The lathe is also fitted with a new type of saddle. A single lever operates both the cross and longitudinal reversible power feeds, which are reversible independently of those to the capstan slide, thereby permitting the cross-slide to be fed towards the operator at the same time as the capstan slide is fed towards the headstock. In addition, the top slide of the saddle has been lengthened, to ensure protection to the bottom slide-ways throughout the stroke. This saddle can also be fitted with a new high-speed chasing attachment, which is automatically tripped by the longitudinal-feed trip-stops. A device for adjustment of depth of cut, fitted to the cross-slide screw, avoids overadjustment and ensures precise and easy setting of the second and subsequent cuts. The automatic trip- and dead-stops, with screw adjustment for transverse motion, are carried in a hand-indexed four-position stop-bar mounted on the right-hand side of the cross-slide and protected by a hinged cover.

Kerry's (Engineering) Ltd.

Of the wide range of equipment exhibited by Kerry's (Engineering) Ltd., of London, E.15, including lathes, drilling machines, ultrasonic drills, and ultrasonic cleaning equipment, particular interest attaches to their new 11 in./13 in. swing lathe and to their Model-78 drilling machine with automatic change for giving instant speed selection without stopping the motor.

The new 11 in./13 in. swing lathe (Fig. 27), which has increased power, greater spindle capacity, and higher speed range, utilizes an all-geared headstock driven by a single-speed 2-hp motor, giving 12 spindle speeds from

Engines perfect for the railways

Rail vehicles with Mercedes-Benz Diesel engines are in service all over the world and experience in practice has shown that the Mercedes-Benz high speed Diesel is particulary well suited as power unit for locomotives.

There are good reasons for this: The Mercedes-Benz high speed Diesels are light and need little space – characteristics required by the railway engineer. They are of robust construction and capable of withstanding high loads; that is why Mercedes-Benz Diesels are dependable – and the railway time table demands reliable engines. Furthermore Mercedes-Benz Diesels are economical: They use little fuel, and they are easy to service.

For every purpose in rail transport there is a suitable engine in the range produced by Daimler-Benz: – for express trains locomotives and rail cars, for shunting and heavy haulage locomotives.

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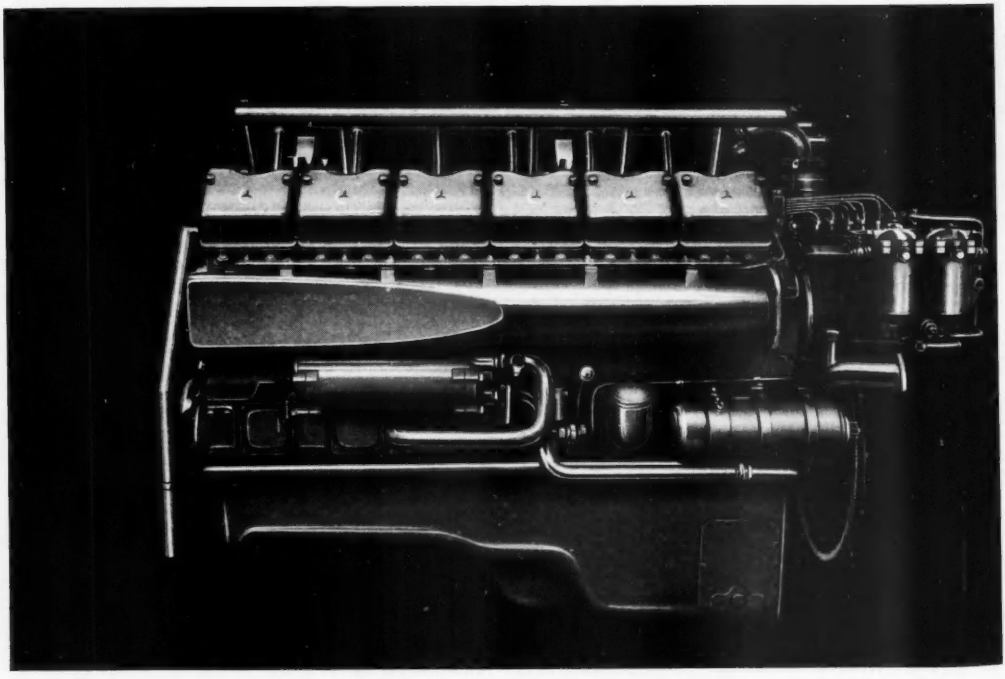


MERCEDES-BENZ DIESEL

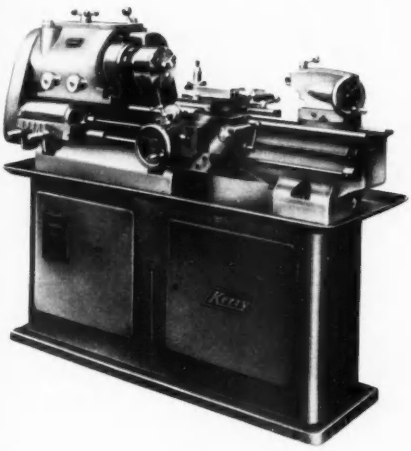


Fig. 27

40 to 2000 rpm. A feed reverse is incorporated. The main spindle has a $1\frac{9}{16}$-in. diameter clearance bore and is mounted on opposed taper roller bearings at the front and a roller bearing at the rear. The Norton-type feed-box gives 55 pitches, from 4 to 448 threads per inch, and includes 19 tpi on the English version or $11\frac{1}{2}$ tpi on the American version. There are seven power feeds available, ranging in geometrical progression from 0·0004 to 0·028 inch per revolution of the main spindle for both surfacing and sliding motions. Engagement of surfacing and sliding motion is by means of a single-lever gate change which is interlocked with the screwcutting lever. A built-in screwcutting dial is standard equipment. The saddle carries a broad Tee-slotted cross-slide and a compound slide adjustable through a full circle.

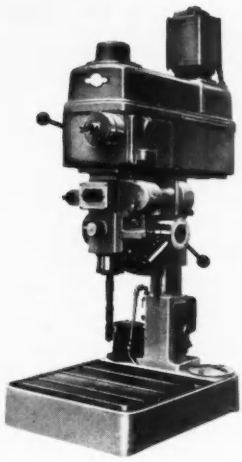


Fig. 28

The Kerry Model-78 drilling machine (Fig. 28) has been designed to provide a versatile, trouble-free machine, combined with ease and speed of operation. In this machine, a 1-hp constant-speed motor transmits power through variable-pitch pulleys and a moulded rubber-and-cord type of Vee-belt, specially constructed with preformed inner cogging to give lengthwise flexibility and crosswise rigidity. The drive is totally enclosed, speed being controlled by a cranked handle conveniently positioned at the front, with a large-diameter dial showing 58 indicated speeds. The head incorporates a separate 2-speed constant-mesh gearbox controlled through multi-disc and multi-sprag clutches. Speed selection can be carried out with the drive fully engaged, change-over being instantaneous. Height adjustment of the head on the column is controlled by a worm-gear operated by a crank inserted at the front. The head can be rigidly clamped in any position by a self-releasing padlock operated by a crank at the side.

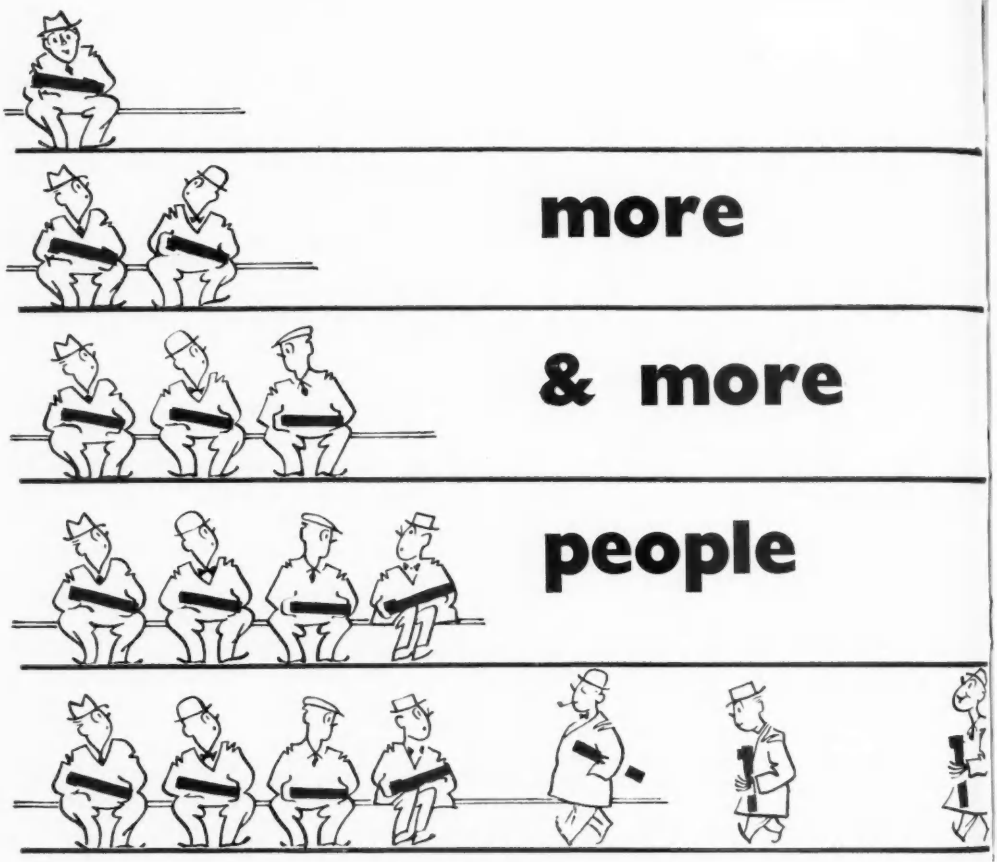
On the standard machine, a sensitive manual feed is provided by means of a capstan-type handwheel through a rack and pinion, the feed hub being accurately graduated and fitted with a positive adjustable depth-stop and a back-stop to limit the return stroke for certain operations. An automatic power feed can be fitted in place of the manual feed, providing three cutting rates, i.e., 0·002, 0·004, and 0·008 inch per revolution, selected with appropriate change-gears. Additional gears are available for intermediate feeds up to a maximum of 0·010 in./rev.

Hilger & Watts Ltd.

The wide range of scientific instruments produced by Hilger & Watts Ltd., of London, N.W.1, and shown on the stand of Alfred Herbert Ltd., of Coventry (the sole selling agents in the U.K.) included a range of projectors, an improved design of surface-finish microscope, a vertical measuring machine with an improved reading system of the projection type in place of the former microscope eyepiece, and a number of new instruments, including a precision clinometer reading directly to 1 sec of arc or by estimation to 0·5 sec, an engineers' "Autoset" level, which automatically maintains a level line of sight, even if the telescope is tilted, and the "Minidekkor", which is a miniature lightweight autocollimator that measures simultaneously angular displacements in two directions.

Other new Hilger & Watts exhibits included a photo-electric micrometer microscope and a photo-electric autocollimator. The photo-electric micrometer microscope is far more accurate and quicker to use than the usual optical equivalent. It is suitable for reading scales and circles where the divisions are marked by lines from 0·0001 to 0·0015 in. in width, the accuracy over the total range of 0·05 in. being 0·00004 in. The instrument is fitted with an eyepiece incorporating a Hilger-Schwartz photocell preceded by a vibrating slit. A setting is made by rotating a micrometer drum until the slit oscillates symmetrically about one of the lines engraved on the scale being read. The meter then indicates zero by the null method, the reading being taken from the micrometer drum.

The photo-electric autocollimator has been developed from the well-known visual instrument and has the same applications, but provides an easier, more rapid, and more accurate method of setting. A single setting has an accuracy of 0·1 sec and reduces operator fatigue caused by repeated exacting observations through the eyepiece. Thus, the normal setting lines, as seen through the eyepiece, are used for preliminary adjustment, after which



use Eclipse

'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd. and are obtainable from all tool distributors.
UH 15

there is no need for further viewing through the eyepiece, which incorporates a Hilger-Schwartz photocell preceded by a vibrating slit. The maximum working distance of the instrument, which is used for determining straightness, flatness, and small linear and angular displacements, is 30 ft. Repetition of setting is within 0·05 sec of arc, the accuracy over the total measuring range being 2 sec of arc.

Firth Brown Tools Ltd.

Exhibits from Firth Brown Tools Ltd., of Sheffield, comprised a comprehensive range of engineers' cutting tools, including drills, reamers, milling cutters, "Zeelock" and Type-3 inserted blade cutters, "Mitia" carbide tools, taps, and all types of screw-threaded tools, as well as "Insto" segmental circular cold saws, hacksaws, saw files, milled-tooth files, wood saws, shear blades, etc., and examples of the company's ability to meet specialized tooling problems, a typical example being illustrated in Fig. 29, which shows a special cutter head developed for the "Atlas" wheel-truing lathe.

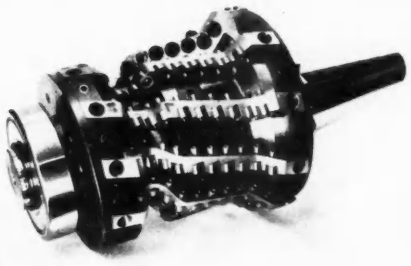


Fig. 29

In addition, demonstrations were given of the "Hardometer" hardness-testing machine, the company's sharpening machine for circular saws with "Mitia" carbide-tipped teeth, and the "Speedicut Chipbreaker" drill, which offers the advantages of chip control without any special re-point grinding, combined with increased rigidity, permitting higher feed rates and increased life between regrinds.

James Neill & Company (Sheffield) Ltd.

An extremely wide range of work-holding devices was exhibited by James Neill & Company (Sheffield) Ltd., of Sheffield 11, including magnetic Vee-blocks, magnetic racks, magnetic links, hand magnets, magnetic floaters and bases for dial-gauges, and a full range of "Eclipse" magnetic chucks. These chucks cover almost any requirements of modern production and range from heavy-duty chucks to fine-pole chucks for machining small parts and their sections. In addition, three entirely new sizes of "Eclipse" chuck were exhibited. These chucks, which have respective working surfaces of 20 × 10 in., 24 × 10 in., and 24 × 12 in., are primarily designed for super-precision grinding on the larger surface grinders. They are not heavy-duty chucks, but make the best use of modern materials, with a closer pole spacing than existing large sizes, provision having been made for these to be modified from standard independent types to multiple units which can be mounted end to end, thus providing a continuous magnetic surface. The top plates of all these wider chucks have a central support which entirely eliminates any tendency towards deflection of the work-holding surface under load, thus making them eminently suitable for the most accurate grinding operations.

The "Eclipse" permanent-electro-magnetic chuck was also exhibited. This chuck ensures the highest possible magnetic efficiency for holding the work to the chuck surface by means of a new principle, in which the permanent-magnet poles are energized *in situ* whilst in actual contact with the workpiece, the electrical current being applied only for magnetizing and demagnetizing, so that any failure or interruption of the power supply cannot affect the efficient holding of the work on the chuck face.

Completing the display was a range of the well-known "Eclipse" tools, including high-speed-steel hacksaw blades, hacksaw frames, tool-holders and tool bits, lathe-tool sets, and boring-tool holders and bits, as well as general-purpose saws for both wood and metal, and two types of sheet saws, one for metal and the other for all kinds of building materials. Other exhibits included swivel and box types of angle plates, automatic centre-punches, scribers, and surface gauges, pin vices, pin tongs, pin chucks, and a range of tap wrenches.

Edibrac Limited

Among other exhibits, Edibrac Limited, of Broadheath, Manchester, featured their new "Standafour" range of sixteen carbide-tipped lathe tools, which are capable of carrying out 90% of turning operations, this standardization providing a considerable saving to users. These tools are available in four popular styles, in four shank sizes, and in grades suitable for machining steel and non-ferrous metals.

Other exhibits included the new "Centralok" milling cutter, which incorporates a mechanically-held throw-away tip, completely eliminating the use of tool and cutter grinders and reducing the down-time required by conventional methods of servicing cutters. Each tip of the "Centralok" milling cutter, which is available in sizes from 5 to 10 in. in diameter, has eight cutting edges, brought into use by a simple indexing operation.

The "Heliform" mechanically-held tipped screw-cutting tool was also shown. This tool has been specifically designed to reduce production times by incorporating in its shank those particular features which normally take so much time to produce when setting conventional tools. The helix angle for any given thread is automatically produced. The tip, which automatically maintains its true form throughout its length, is of the circular type and is equal to 2¼ in. linear length, form-ground around the entire perimeter.

In addition to the new range of Edibrac carbide-tipped tools designed for use with the "Copymax" range of profiling tools, the Jones-Shipman-Edibrac tool-holder with throw-away tips was also shown. This tool offers considerable advantages in both production and jobbing shops, down-time being reduced and regrinding and resetting costs being eliminated. The tip seating on the holder itself is precision-ground on all locating faces, while the inserts, either square or triangular, are precision items, ensuring true location when indexed or replaced. The square inserts have eight effective cutting edges, and the triangular inserts six effective edges, each edge being brought into operation by a simple indexing arrangement. Chip-breakers, which form an integral part of the holder, can be adjusted to suit feed and speed conditions.

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Dowding & Doll Ltd.

As is only to be expected, an exceedingly wide range of equipment was exhibited by Dowding & Doll Ltd., of London, W.14, including examples of Dowding universal and horizontal hobbing machines, "Accuratool" automatic high-speed precision capstan lathes, and British Wiedemann turret punch presses. Other exhibits included representative examples of Ahcol "Rotamill" semi-automatic rotary milling machines, Dixi horizontal optical precision jig-boring machines, Hunkemoller universal precision knee-type milling machines, Menziken vertical automatic lathes, Oerlikon production jig-boring machines, high-speed hydrocopying lathes, and tool and cutter grinding machines, Reishauer grinding and lapping machines, "Rigid" automatic hydrocopying die-sinking machines and knee-type milling machines, Saut-du-Tarn vertical sliding-head drilling, boring, and tapping machines, Tripet cylindrical and universal grinding machines, and de Vallière double-ended precision fine-boring machines.

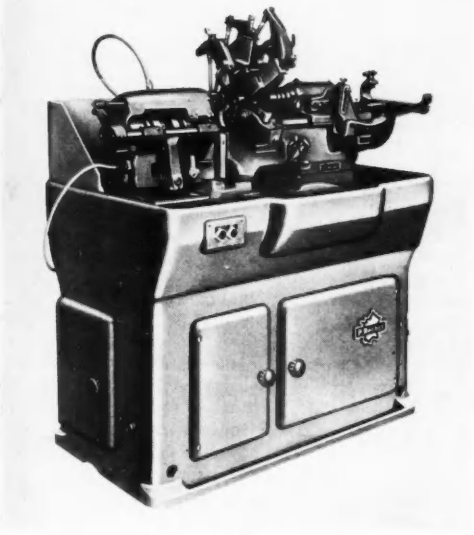


Fig. 30

Other exhibits by Dowding & Doll Ltd. included the Béchet single-spindle sliding-head automatic lathe, Model M.1660, and the Innovations Mécaniques high-production multi-tool lathe, Model T.6. In the Béchet machine (Fig. 30), the guide-bush supports the work close behind the tools, permitting long and slender work to be machined with extreme precision. Each of the five tools in the radial tool bracket is provided with a precision micrometer setting, both radially and axially, and the rocking tool bracket is exceedingly robust and has a large clamping area. The 3-spindle drilling and tapping slide is actuated by a rack-and-lever device which ensures optimum utilization of the cam profile. Spindle feeds can be engaged while indexing. Twenty spindle speeds, ranging from 570 to 5700 rpm, are available, together with fifty camshaft speeds, from 0·1 to 30 rpm. An accelerator device is incorporated into the camshaft drive, reducing idle machine movements. Headstock movement is controlled by flat or bell-type cams, a double follower permitting two cams to be used conjointly.

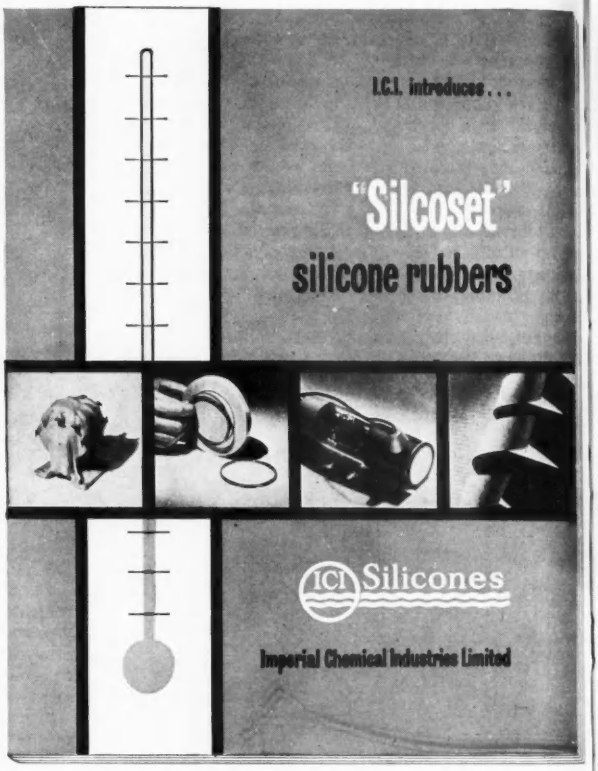
Fig. 31

The Innovations Mécaniques high-production multi-tool lathe, Model T.6, has been specially developed for rapid, accurate, heavy-duty machining. As such, the headstock spindle is supported on three precision bearings, and the tailstock is of exceedingly robust construction. Similarly, the carriage and cross-slide assembly of the machine (Fig. 31) is of unusually large proportions, accommodating multi-tool holders at both the front and rear, its robust design permitting rapid machining with carbide tools. Four adjustable precision micrometer stops control longitudinal movement of the carriage, while four quick-action stops are provided for depth-setting of the front tools, with a micrometer stop for the rear tools. Conveniently located levers control the twelve spindle speeds (45 to 2000 rpm), forward and reverse, and also the spindle brake, which permits instantaneous speed changes to be made. Nine feeds are provided, longitudinal feeds ranging between 0·002 and 0·032 in., and transverse feeds between 0·0007 and 0·0120 in. The machine, which is provided with pneumatic chucking, has a maximum swing over the bed of 17½ in., and a maximum distance between centres of 27½ in.

A. A. Jones & Shipman Ltd.

Of the extensive range of equipment exhibited by A. A. Jones & Shipman Ltd., of Leicester, particular interest undoubtedly attaches to a new technique for simplifying ball-stud processing. This technique, which involves the use of special ball-end milling and honing machines manufactured by The Micromatic Hone Corporation, of Detroit, was demonstrated under power.

This technique makes it possible to process the ball directly from the forging, using a special machining method comprising two operations. Accuracy is obtained by canting the ball-stud and by using a special double tool. A constant cutting speed is ensured in both operations by positioning the stud on an inclined axis, with the centre of the ball at the crown, and the point at which the shoulder intersects the sphere in a horizontal plane. Microhoning of the ball-stud is performed on a special machine, after it has been milled on a similar machine designed for the roughing operation (Fig. 32).



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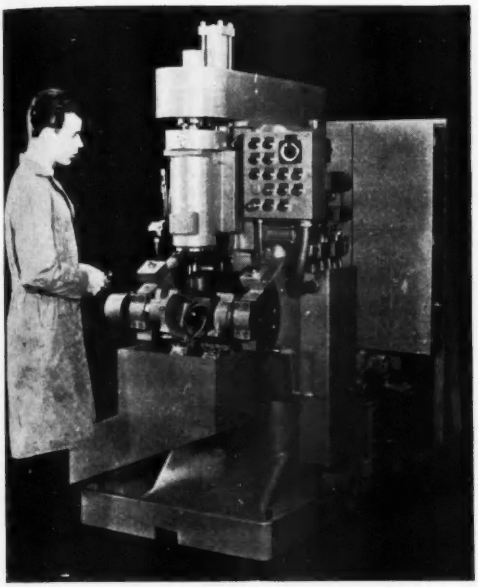


Fig. 32

A unique cutting tool with a solid body, U-shaped at the cutting end, is used for roughing and utilizes two round tungsten carbide blades which can be turned to a total of six different cutting positions. For honing, the special abrasive cup wheel is mounted on a ball float, so that the same axes are used as when roughing. As an example, it may be said that, in a particular application involving the production of ball-studs of 1¼-in. diameter, the roughing operation removes approximately 0·068 in. of stock in a 15-sec floor-to-floor cycle, including loading, clamping, and ejection, the finish being from 40 to 60 micro-inches r.m.s., with sphericity held to a total error of 0·0005 in. The part is then transferred to the honing machine for the production of the final geometrical accuracy, the floor-to-floor cycle time in this case being 24 sec. In this operation, 0·002 in. of stock is removed, the resulting finish being from 6 to 10 micro-inches r.m.s., with sphericity held to within 0·0003 in.

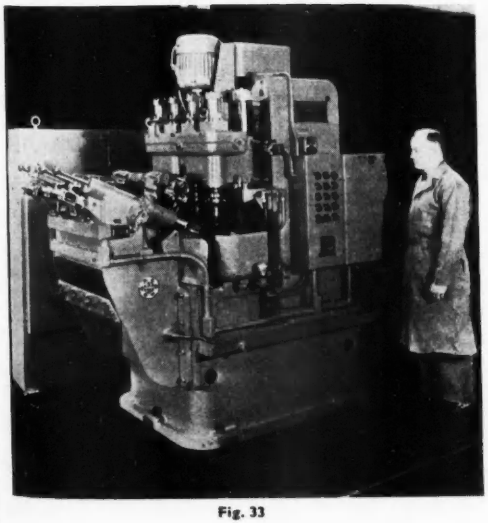


Fig. 33

The Micromatic Hone Corporation have developed a range of automatic multi-spindle milling and honing machines designed to give a maximum rate of production, combined with a very accurate finish. On the four-spindle machine shown in Fig. 33, the work parts are automatically fed, located, clamped, microhoned, and ejected. Abrasive feed and raising and lowering of the head with its four spindles are controlled hydraulically. This machine is capable of producing over 600 balls of 1¼-in. diameter per hour.

Pearson Panke Ltd.

Exhibits from Pearson Panke Ltd., of London, N.W.7, mainly comprised examples of the range of equipment produced by Schuler, of Goeppingen, and included high-speed notching machines, trimming machines, thread-rolling, trimming, and beading machines, and a representative selection of presses, including C-frame power presses, extrusion presses, a 160-ton transfer press, and a Schuler-SMG hydraulic drawing press.

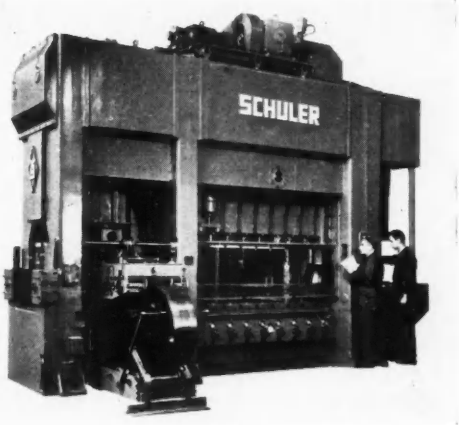
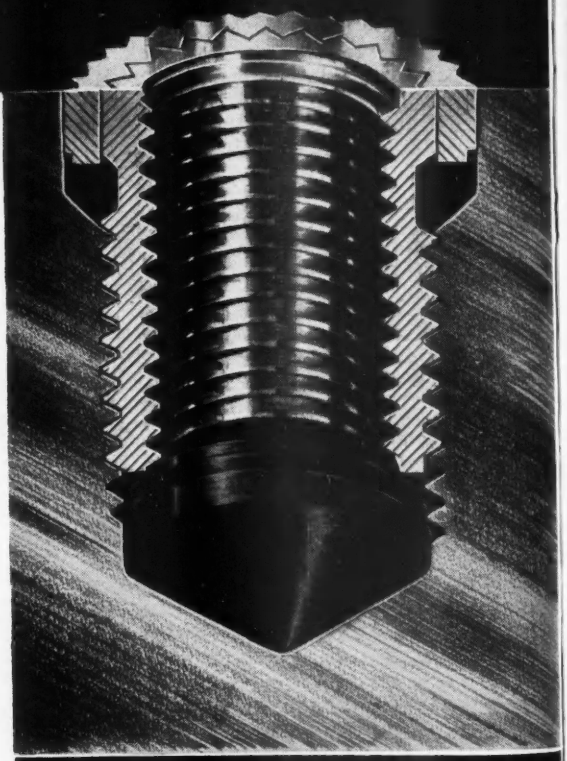


Fig. 34

The Schuler transfer press (Fig. 34) is the Model PSt 160/11/360, which is a 160-ton unit with 11 tool stations, a tool pitch of 360 mm, and a stroke of 380 mm, the number of strokes being infinitely variable between 12 and 36 per minute. Since special arrangements are made for rapid tool-changing, such as the use of joint bolster plates for the set of tools, and calibrations for all the different settings and adjustments, etc., these presses are suitable not only for the production of very large batches, but also for the economical production of medium-size batches. All motions are extremely smooth, reducing vibration to a minimum. The pitmans are housed in the uprights, so that the pressures from the ram are transmitted directly to the anchor columns. As a result, there is no bending stress imposed on the headpiece. In addition, it is possible to provide a pressure stage immediately underneath the pitman in the right-hand upright for embossing or sizing work, without any harmful effects on the remaining tool stations. The machine and tools are completely safeguarded against damage by means of a series of devices which switch off the machine immediately in the event of a component not

a tough thread in a soft metal



A common problem and one which restricts the application of light metal components. Now, for the first time it can be really satisfactorily overcome.

ROSAN INSERTS provide permanently locked threads of hard wearing steel in soft metals. They are simple to install and reliable under all conditions.

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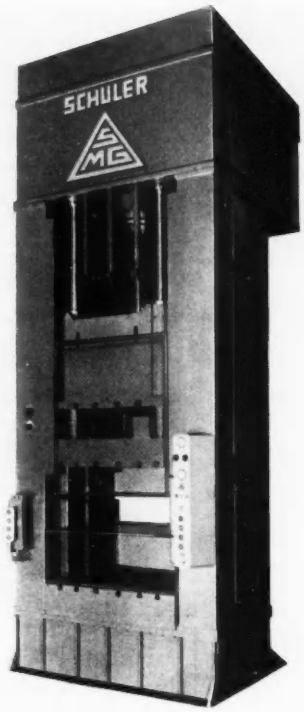


Fig. 35

being ejected in any tool station or if a fault develcps in the air supply, lubrication system, etc. These devices operate in conjunction with a Schuler single-plate clutch and brake. The reduction and main gearwheels in the gearbox and in the uprights are provided with helical and double-helical gearing which, in conjunction with the lubrication system used, ensures very quiet operation.

The Schuler-SMG hydraulic drawing press exhibited (Fig. 35) is the Model HZPUX 100/50. This 100-ton press is a double- and treble-acting model and is the first of its range to be exhibited in the U.K. This machine features a variable-delivery axial-piston pump with a constant-power device for enabling the pump to provide a high rate of flow at low pressure or a lower rate of flow at high pressure. The upper sheet-holder ram moves below the main ram, so that any tilt in the sheet-holder is not transmitted to the drawing ram. On the standard machine, the sheet-holder pressure is generated by means of four differential pistons by the main ram in such a way that only 20% of the sheet-holder pressure has to be subtracted from the main-ram pressure. This arrangement eliminates the need for a separate pump for the sheet-holder. The pressure in each of the four cylinders is controlled independently—a particularly useful feature when drawing irregularly shaped components.

By operating change-over valves, the sheet-holder cylinders can also be connected to the main pressure circuit. It is therefore possible to operate the machine as a single-acting press, as a double-acting press, and as a treble-acting press. For operation as a single-acting press, the drawing ram and sheet-holder ram are coupled together, whereas, for operation as a double-acting press, they operate with their respective maximum pressures. For treble action, a hydraulic drawing cushion can be fitted to the press, this cushion also serving as an ejector for the drawn component. The hydraulic drawing cushion in the table is fitted with a pressure-control device, by means of which it is possible to vary the cushion pressure during the stroke.

The machine exhibited was fitted with a photo-electric guard, which incorporates a scanning beam, so that the area to be guarded is covered completely without any gaps. A special advantage of this guard is that it is extremely robust and does not require careful aligning. Furthermore, in the unlikely event of guard failure, it will automatically fail-safe, while an additional self-monitoring device ensures that, if the guard does not respond, the press cannot operate. Other features of the machine include thermostatically controlled oil heating and cooling and the fitting of timers, which enable pressure to be applied for periods up to 10 sec at the bottom of the stroke, and to allow the ram to rest for periods up to 10 sec at the top of the stroke, when continuous operation has been selected.

Delapena & Son Limited

As they are now organized into two separate divisions, respectively responsible for induction heating and precision honing equipment, it is not surprising that the central feature of the exhibits by Delapena & Son Limited, of Cheltenham, covered examples from both divisions. In this case, the central feature of their exhibits combined both induction heating and honing in a practical fully automatic set-up for hardening cylinder liners with minimum distortion and honing the bores to close tolerances of accuracy and surface finish. This set-up involves the use of an induction heater, an intensifier for bore hardening, an automatic traversing, transfer, and clamping fixture, a vertical honing machine, and automatic sizing equipment.

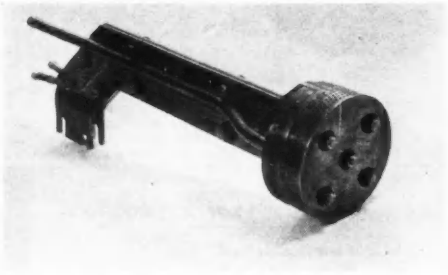
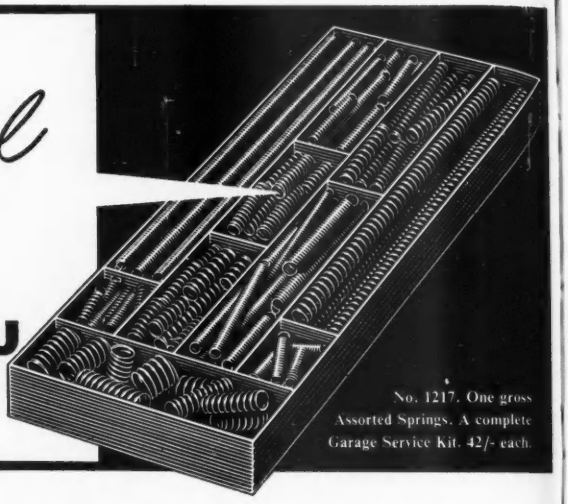


Fig. 36

The induction heater used is the Model E 50, which is a standard radio-frequency valve-oscillator type of generator operating at a frequency of 220 kcs and a maximum continuous power output of 50 kW. The intensifier for bore hardening is a new form of the Delapena patented intensifier (Fig. 36) for progressive hardening inside cylindrical surfaces by axial traverse, with a following spray quench. The intensifier is coupled to the generator by water-cooled flexible leads and a radio-frequency transformer.

The automatic traversing, transfer, and clamping

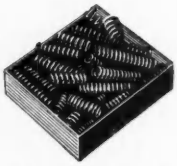
THAT *Experimental Spring* YOU WANT IS WAITING FOR YOU IN THIS BOX ...



No. 1217. One gross Assorted Springs. A complete Garage Service Kit. 42/- each.

If not, try another box in the Terry Assorted Springs range

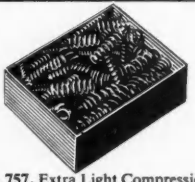
No. 1200. Three dozen Assorted Light Expansion Springs, suitable for carburettor control, etc. **13/6.**



No. 98A. Three dozen Assorted 1" to 4" long, $\frac{1}{4}$" to $\frac{3}{4}$" diam., 19G to 15G. **5/6.**

No. 753. Three dozen Assorted Light Expansion $\frac{1}{2}$" to $\frac{1}{4}$" diam., 2" to 6" long, 22 to 18 S.W.G. **10/6.**

No. 760. Three dozen Assorted Light Compression Springs. 1" to 4" long, 22 to 18 S.W.G., $\frac{1}{8}$" to $\frac{1}{2}$" diam. **6/6.**



No. 757. Extra Light Compression, 1 gross Assorted, $\frac{1}{4}$" to $\frac{7}{16}$" diam., $\frac{1}{2}$" to 2$\frac{1}{2}$" long, 27 to 19 S.W.G. **15/-.**

No. 758. Fine Expansion Springs. 1 gross Assorted $\frac{1}{4}$" to $\frac{3}{4}$" diam., $\frac{1}{2}$" to 2" long, 27 to 20 S.W.G. **15/-.**

We know *exactly* how difficult it is to find springs for experimental work . . . we've been making quality springs for over 100 years. So, we confidently offer you our excellent range of small boxed assortments which covers a very wide range.

We can only show a *few* boxes. Send us a p.c. for our full list. If ever you are stuck with a spring problem let our Research Department put their long experience at your disposal.

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fixture is a combined unit which receives the cylinder liner, transfers it to the induction-heating station, vertically traverses the liner past the intensifier while rotating it, transfers the liner to the honing station, clamps it during honing operations, and transfers it to the unloading station. Operation is continuous, so that loading, hardening, honing, and unloading take place simultaneously. The Model-VHM 3C vertical honing machine used is the latest, completely redesigned version, incorporating new methods of drive and control. This machine is suitable for use with completely automatic or semi-automatic production lines and with automatic sizing devices.

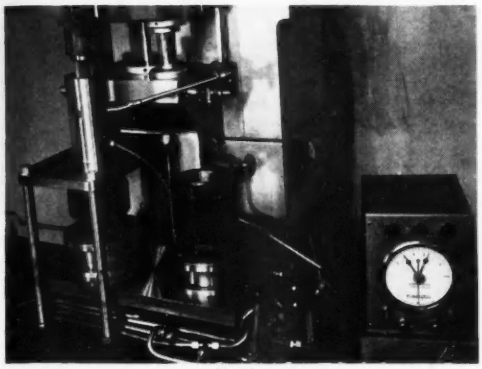


Fig. 37

The time cycle of the set-up is governed by the time taken for the longer operation, which, in this particular demonstration, was the honing operation. Switching is controlled by Delapena automatic sizing equipment, which is a new method of automatic air-gauging developed by Delapena in conjunction with Teddington Industrial Equipment Ltd. and which was shown for the first time. This equipment (Fig. 37), which uses clean, dry compressed air at between 50 and 150 psi, consists of a gauging plug and a control unit. The gauging plug, which is arranged to enter the workpiece at each stroke of the hone, has two or three radial nozzles fed by an air supply from the control unit, which houses two electro-pneumatic relays and other control and indicating equipment. These relays are extremely sensitive and respond to signals from the gauging head, indicating on a large dial variations in the diameter of the bore being honed. Amplification is adjustable to give full-scale deflections of from 0·001 to 0·005 in. The two relays are adjustable and can be set to operate at any size within the range of the instrument. Warning lights indicate when the lower limit, required size, and top limit have been reached.

Keeton, Sons & Co. Ltd.

A comprehensive range of their "Keetona" sheet metalworking machinery was shown by Keeton, Sons & Co. Ltd., of Sheffield 9, a member of the Firth Cleveland Group. In addition to two entirely new machines, i.e., a 4-ft treadle guillotine and an 8-ft × $\frac{1}{8}$-in. power bending roll, exhibits included two 8-ft power guillotines, with respective capacities of $\frac{1}{4}$ and $\frac{1}{8}$ in., and working demonstrations of a 10-ft × $\frac{1}{4}$-in. power guillotine with hydraulic hold-down and power-operated back gauge, and also of a 6-ft × $\frac{1}{8}$-in. power guillotine.

A section of the exhibits was devoted to products of the Hollow Boring Division of the company. This division specializes in the production of hollow bored bars, with special emphasis on deep boring for the machine-tool, aircraft-engine, heavy-machinery, chemical, and petroleum industries.

W. & T. Avery Ltd.

A wide range of testing machines was exhibited by W. & T. Avery Ltd., of Birmingham 40, including a production spring-testing machine, a direct-reading hardness-testing machine with a capacity of 150 kg, and a visual hardness-testing machine with a capacity of 120 kg, fitted with a dual-magnification microscope of ×70 and ×350. Other exhibits included two self-indicating and mechanical recording machines for recording extension between grip-holders, a dynamic balancing machine with belt drive snd alternative induction drive, and an electro-dynamic balancing machine with a capacity of 250 lb, fitted with a twin vectometer indicator head and plane compensator.

Vectometers with light-spot indication have been introduced by the company to enable unbalance readings to be expressed as conspicuously as possible. The frontal appearance of such an instrument is shown in Fig. 38, in which the light spot is displaced from the centre zone, so that the radius at which it settles represents the amount of unbalance, and the position on the scale the angular location on the rotor. Each vectometer has two wattmeter instruments spaced at 90 deg., one arranged to deflect the light spot vertically with the aid of a mirror, while the second acts independently and deflects the light spot horizontally. The indicated result is fixed by means of an electromagnetic locking device, so that writing down and recording the readings are not necessary.

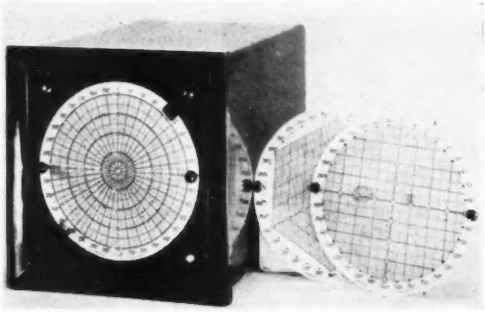


Fig. 38

The front scale of these vectometers can be exchanged, so that a polar display can be replaced by a special diagram from which components of 90 deg., or alternatively at 120 deg., as shown in Fig. 38, can quickly be seen by the operator.

Solex (Gauges) Ltd.

In addition to "Mecalix" transducers and dynamometers for the determination and assessment of cutting forces, Solex (Gauges) Ltd., of London, W.4, exhibited an extemely comprehensive range of air-operated gauging equipment for both production and inspection requirements, including Solex direct air-jet plug gauges for the internal measurement of bores to a minimum size of 0·118 in.

Other exhibits included a standard internal comparator with a 200-mm diameter base and incorporating four measuring bodies, permitting a range of diameters from 0·118 to 8 in. to be covered. In addition, two types of

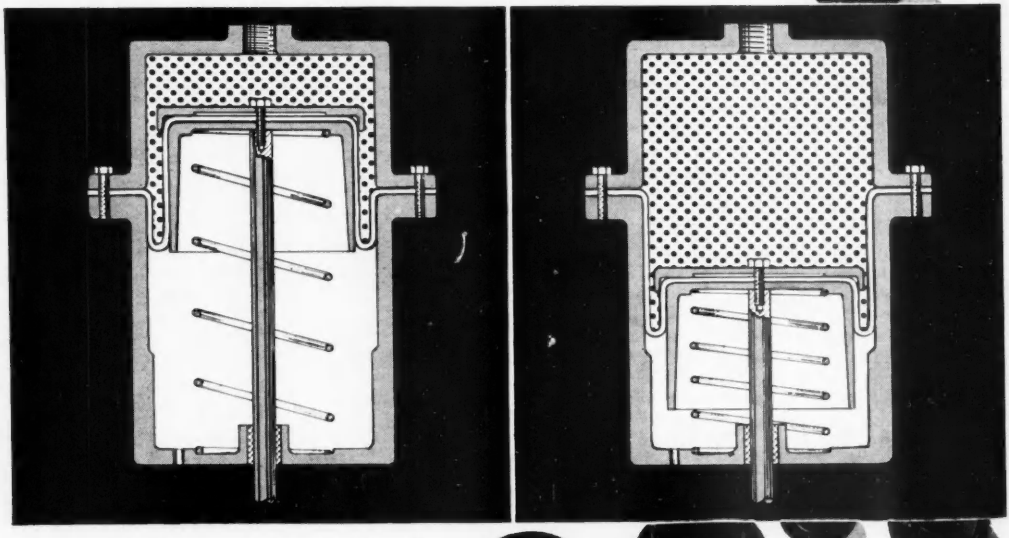
REGD. TRADE MARK

ROLLING DIAPHRAGMS

The rolling action of these supple, thin-walled Bellofram diaphragms brings many advantages for hydraulic or pneumatic devices where frictionless, long stroke action is necessary.

The flexible diaphragms keep a perfect seal within the cylinder in all piston positions. They are non-porous and leakproof and, because free positioning, are supremely responsive to the slightest pressure change.

The smooth rolling action of the diaphragm ensures freedom from abrasive wear . . . renders close machine tolerance in piston and cylinder unnecessary . . . and — (there is virtually no mechanical spring gradient) — ensures frictionless, completely accurate operation. The quality of the diaphragm itself ensures millions of cycles with minimum attention . . . and can be adapted to a wide variety of applications.



Forming a perfect seal when conforming closely to the piston, the Bellofram diaphragm rolls off the piston sidewall and on to the cylinder as it descends; all the time a perfect seal is maintained.

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external comparators were shown, with magnifications ranging from ×4000 to ×23,000. A special contact unit, i.e., the 4M, was also available. This unit can be used on extremely small diameters and permits high magnifications, i.e., ×6000 to ×20,000.

Comparators, caliper units, and continuous grinding calipers for use at the machine were also shown, as well as a hopper-fed automatic sorting gauge, which was demonstrated grading roller components into various classifications in increments of 0·0001 in.

E. M. I. Electronics Ltd.

In addition to a display of rotary and linear "Emicon" inductor micropositioning devices for machine-tool control, a two-dimensional control cabinet, and the latest type of Creed teleprinter, E.M.I. Electronics Ltd., of Hayes, Middlesex, exhibited for the very first time a new low-priced tape-controlled electronic positioning system with a nominal electrical accuracy of 1 part in 400,000. Known as the "Emicon 400" positioning system, this equipment positions heavy workpieces on medium and large machines and does not require the use of a specially designed positioning table. Speeds up to 300 ipm can be controlled by the system, which measures the rotation of a leadscrew or pinion, and is therefore adaptable to many existing machines. The datum point can be located anywhere in the travel of the workpiece, and a more comprehensive range of instructions than usual can be programmed on the tape.

Another automation aid demonstrated for the first time was the company's new large dynamic balancing machine, which is designed for checking the degree of unbalance in high-speed turbines, large armatures, and other rotors up to 250 lb in weight. The use of a new type of transducer and of a new technique in cradle suspension enables a bearing displacement of 8 micro-inches to be detected readily.

Keelavite Hydraulics Limited

An extremely wide range of actuators and control units, including hydraulic pumps, motors, and valves, was exhibited by Keelavite Hydraulics Limited, of Allesley, Warwickshire. Of these, new developments and additions to the Keelavite range include a complete range of "M"-type hydraulic power packs, which are self-contained assemblies comprising a hydraulic pump with a suitable prime mover and control valves, housed in an oil reservoir. These units merely require connection to hydraulic actuators and a suitable electrical power supply to provide a complete hydraulic system.

Another recent development is a special hydraulic pump with integral relief and non-return valves. This unit, which is specially suitable for machine-tool applications, supplies power to hydraulic actuators, its special festure being that the actuator can be reversed simply by reversing the electric motor. In this way, complicated valve gear is eliminated, with a considerable saving in space, weight, and cost.

The new Keelavite electro-hydraulic servo-valve was exhibited for the first time. This valve, which enables hydraulic systems to be very accurately controlled electronically, basically consists of a rotary torque motor driving a pilot valve, which provides one stage of hydraulic amplification, to control the position of a second-stage piston. The first stage comprises a nominally zero lapped 3-way valve, driven against springs by the torque motor, which is fitted with balanced windings of either low or high impedance. The second stage consists of a conventional piston-type valve, which may be fitted with either a 4-way or a 5-way piston. The servo-control unit consists of a torque-motor amplifier, two error amplifiers, two phase-sensitive rectifiers, and a.c. and d.c. power supplies.

Fig. 39

In operation, the centre (jack) port of the pilot valve is connected to one end of the second-stage piston, whilst full servo-pressure is applied to the other end, which is half the area of the first end. Full servo-pressure is applied across the pilot valve, so that, if the pilot valve is centred, balanced forces are applied to the ends of the second-stage piston since, under these conditions, the pressure at the jack port is half the servo-pressure, and the second-stage piston will remain stationary. A small deflection of the pilot valve disturbs the force balance, and the velocity of the second-stage piston becomes proportional to the deflection of the pilot-stage piston and to the electrical input signal to the torque motor. In order to make the position of the second-stage piston proportional to the input signal, a feedback loop is closed around the second stage, an inductive pick-up of the rotary type, driven by a crank actuated by one end of the second-stage piston, being used for this purpose.

At present, two sizes of this valve are available, i.e., type 5545, giving a flow of 25 to 30 gpm for a pressure drop of 1000 psi, and type 5572, giving a flow of 100 gpm for a pressure drop of 1000 psi. The type-5545 valve is illustrated in Fig. 39.

A.R.O. Machinery Co. Ltd.

An extremely comprehensive range of portable spot-welding equipment, from very light hand-operated welding guns to very large production units, was exhibited by the A.R.O. Machinery Co. Ltd., of London, S.W.13. All these welders are complete with automatic process-control equipment, ranging from simple weld timers to complete process controllers giving fully automatic five-stage sequencing.

In addition to the well-known ARO Types M30 and M30V bench welders, two new pedestal welders, i.e., the foot-operated M304 and the air-operated M314 spot/stitch welder were shown for the first time. Robust in design, very accurately controlled by process timing, and extremely simple to set up, both these welders are capable of welding mild-steel plate up to 8 + 8 s.w.g. and non-ferrous metals up to 18 + 18 s.w.g.

Also exhibited for the first time were Type-DP60 air-operated weld/press units, which basically comprise a tapped welding transformer, complete with multi-stage cylinders, electrically operated valves, and secondary jumpers. Operating on the series-welding principle, the pitch adjustment on each unit is from 1 to 4⅜ in. The

Do you wait for hot water on a cold Monday morning?

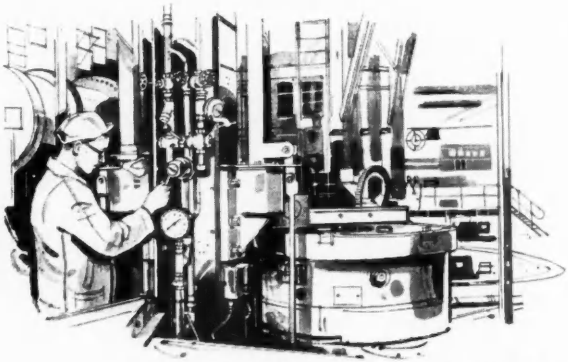
Where hot water is provided from a storage system there is a waiting period when production starts, for the water to heat up in the storage tanks.
With Leonard Steam Water Mixers there is no waiting period. Hot water is available as soon as the steam is turned on.

How would you raise the temperature of a spray very gradually from cold to 120 degrees?

Leonard Valves fitted to the sparge pipe on a cloth scouring and milling machine enable the scourer to vary the temperature to suit the work and to make changes in the temperature during the process gradually, giving a cleaner scour and a better finish.

Do you use cold water when you would like to use hot?

When vegetables are cleaned for canning they are washed in a running stream of water. If the water is too cold the girls' fingers get numb and their production slows down. If it is too hot the vegetables are spoilt. A Leonard Valve looks after the temperature, the girls' fingers and the vegetables.



These are specific examples. Your use of Leonard Thermostatic Steam Water Heaters will probably be different. Write for help. (Our folder H/24)

WALKER CROSWELLER & CO. LTD.

Cheltenham. Telephone 56317

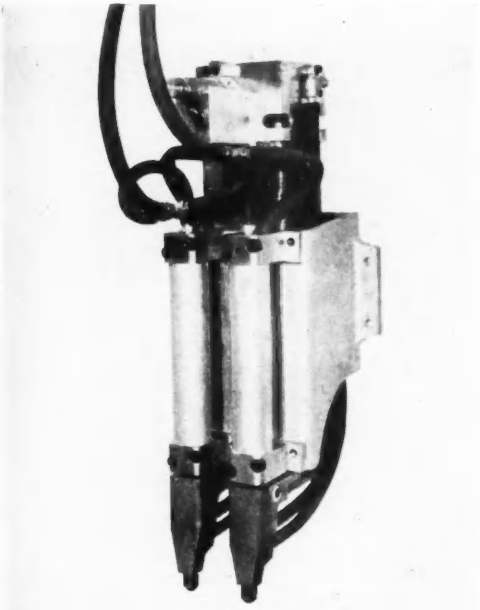


Fig. 40

output of the welding transformer is 10,000 A when welding 20 + 20 s.w.g. mild steel, and a built-in pressure switch ensures that welding current cannot be initiated until full pressure has been built up on the electrodes. These units, one of which is shown in Fig. 40, can be mounted in banks for multi-welding applications and can be controlled from one ARO control panel.

British Indicators Limited

In addition to their new range of super-sensitive dial indicators, which incorporate hardened and lapped pinions throughout, greatly improving sensitivity and accuracy, British Indicators Limited, of St. Albans, Herts., exhibited a number of special instruments developed for multiple-gauging set-ups and incorporating "John Bull" frictionless transmission units. These units are now standard production items in the company's range and can readily be adapted for a wide variety of measuring purposes.

Also on show was the recently improved range of "John Bull" small-bore gauges, which now include screw-in adjustable contact points, facilitating the rapid setting of this range of gauges. In addition, the 1050 "Check-master", for which a number of new applications has recently been developed, was demonstrated in use on gear and pinion testing.

AEI-Birlec Limited

Two furnaces were shown in operation by AEI-Birlec Limited, of Birmingham 24, these being a Birlec sealed quench furnace embodying new design features, and a Birlec GP.1000 box furnace, the smallest in the completely restyled range of general-purpose furnaces. Incidentally, this is the first time that a furnace in the new GP.1000 range was shown in public. These furnaces are built for two temperature ranges, i.e., five Model-GP 1000 furnaces for temperatures up to 1000° C, and four Model-GP.1400 furnaces for temperatures up to 1400° C. Although the standard range is equipped with handwheel-operated door-gear, the model shown was arranged for pneumatic operation, which is available as an optional extra.

Although the Birlec sealed quench furnace demonstrated was engaged in clean hardening, it is also suitable for a wide range of heat-treatment processes, including gas carburizing, carbo-nitriding, carbon restoration, and normalizing. As the charge is fully protected from oxidation throughout the complete heat-treatment cycle, scaling and decarburization are eliminated. Provision can be made for hot oil quenching. The most significant modification to the design is that the furnace chamber is now heated by horizontal radiant tubes, which give longer life and are more easily replaced than the vertical tubes previously fitted. Birlec sealed quench furnaces are available in three standard sizes, with working capacities of 2·5, 9, and 20 cu ft, and can be heated by either U-shaped gas-fired radiant tubes or straight electric radiant-tube elements. The demonstrations were carried out on a gas-fired model of 9-cu ft capacity rated at 1400 cu ft/hr. Protective atmosphere for the furnace was provided by a 250-cfh Birlec endothermic gas generator, simple adjustment of the generator ensuring the supply of gas having the desired composition. Provision is made for the accurate addition of hydrocarbon and/or ammonia directly into the furnace, according to process requirements.

Electric Resistance Furnace Company Limited

Exhibits from the Electric Resistance Furnace Company Limited, of Weybridge, Surrey, included an endothermic atmosphere generator with an output of 100 cu ft per hour, and a mixer for the precision mixing of gas and air for use in atmosphere generators. Other exhibits included the EFCO brazing-paste applicator and a new EFCO small-size closed quench furnace.

The brazing applicator, which is a single unit designed to save time, labour, and material when applying brazing materials in paste form, basically consists of a sheet-metal cabinet housing a foot-switch, an air line, and a paste container, providing a working surface of 3 ft in height. The unit is arranged for connection to a compressed-air supply, the paste being forced through a nozzle, mounted vertically above the top of the cabinet, by operation of the foot-pedal.

The new closed quench furnace is a compact and inexpensive unit for carbo-nitriding, gas-carburizing, and hardening processes. The furnace is heated by electric radiant-tube elements operating at mains voltage, the controlled atmosphere being obtained from a liquid-hydrocarbon drip-feed unit. The general design of the furnace is similar to that of the larger furnaces, an outer door giving access to a water-cooled purging chamber, and an inner heat-insulated door to the horizontal heating chamber. Both doors are operated by air cylinders, and the outer door is fitted with a gas screen. The purging chamber accommodates the single-deck quench elevator used to lower the work into the oil-quench tank. The oil is water-cooled and is circulated by an electrically driven agitator. The heating elements are positioned on the walls of the furnace chamber and below the hearth, and a fan, driven by a water-cooled electric motor mounted on the roof, circulates the furnace atmosphere and speeds the heating. The furnace accommodates a work basket 14 in. long, 8 in. wide, and 8 in. high.

BRYMILL

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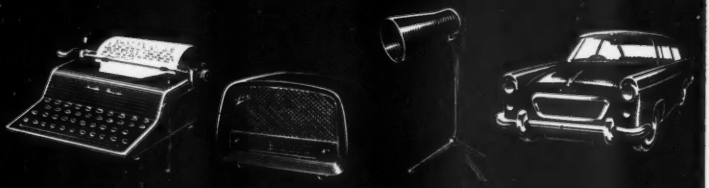

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British Industrial Developments

Automatic Seam-Welding Machine for Large Storage Tanks

Stated to provide a means of welding which is ten times faster than is possible with conventional methods, the "Circomatic" automatic seam-welding machine, introduced by Rockweld Limited, of Croydon, Surrey, is mainly intended for the automatic field welding of horizontal girth seams in large oil-storage tanks or other similar tanks used in the pertroleum and chemical industries. The machine is designed to operate in the horizontal/vertical position under all climatic conditions and with sufficient flexibility to deal with any irregularities in "fit-up" encountered in such large structures.

The machine (Fig. 1) consists of two enclosed platforms straddling the tank wall, the upper edge of each ring of plates being used to form a track, on which the machine runs in monorail fashion. The platforms thus constitute two suspended and symmetrical cabs which house the welding heads, the control gear, and the operating devices, the complete unit accommodating two operators and fitted with tarpaulin weather protection and a central lifting eye. The upper carriage runs on two grooved wheels, suitable for use on plate edges up to 2 in. in thickness, the wheels being carried in vertically pivoted frames with a screw adjustment to suit varying plate radii. Only one of the wheels is motorized, the drive being effected by a totally enclosed motor through a variable-speed gear and a two-speed reducer, giving speed ranges of either 10 to 100 ipm or 80 to 200 ipm. A clutch enables the machine to be positioned by hand, and the two operators (one on each side of the plate) can communicate through throat-microphone telephones.

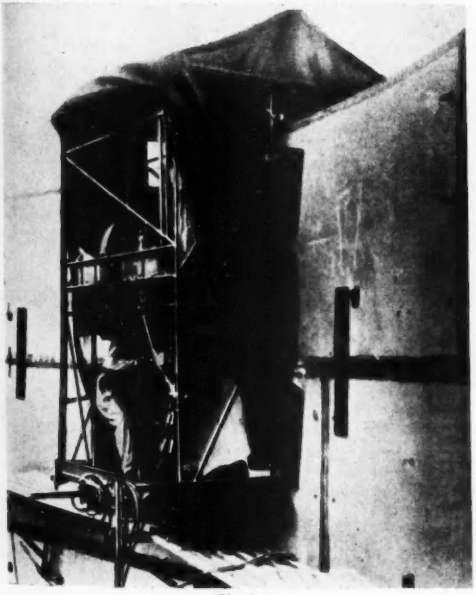


Fig. 1

The "Circomatic" machine makes use of the Rockweld "Comet" process, which employs a continuous composite wire fused in an atmosphere of carbon dioxide. The wire, $\frac{1}{8}$ or $\frac{5}{32}$ in. in diameter, is rolled from steel strip and is not a tube, but a complicated formation, with the flux tightly entrained in the interstices, and is mechanically strong enough to be fed without deformation through the feed rolls. The mechanical and metallurgical properties of the weld are controlled by the flux, and the wire is therefore made in various grades to suit specific welding conditions.

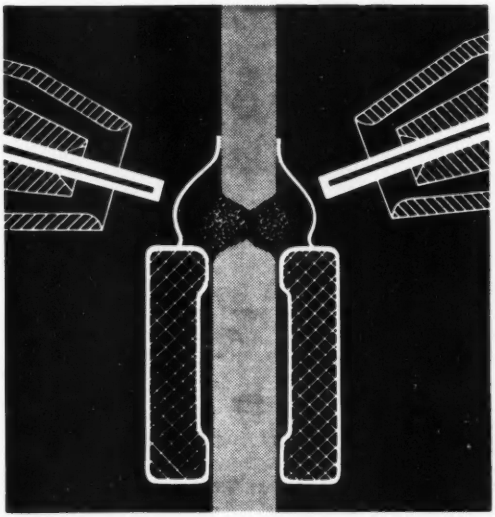
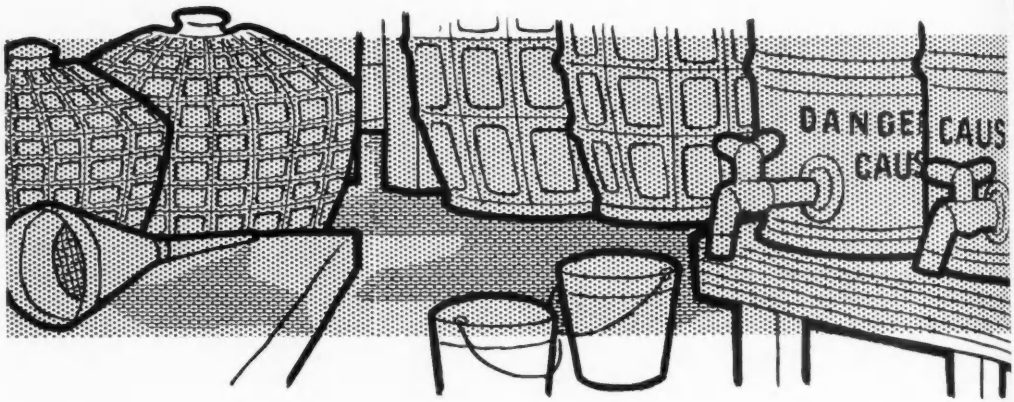


Fig. 2

Two welding heads are used, these being set in the manner shown in Fig. 2. One head leads the other by a short distance, e.g., about 1 ft, provision being made to adjust this distance to allow the weld in the second side to be made under optimum conditions. Both sides of the joint are welded simultaneously, the arcs being visible throughout the operation. The welding heads are of the double-motor type and are provided with nozzles to suit $\frac{1}{8}$- and $\frac{5}{32}$-in. wire, each head being mounted on the welding arm by supports which provide universal movement for position and quick-action adjustment as welding proceeds. A fabricated arm, pivoted on a column, is fitted in each cab to carry the welding head. The arm has a motorized raising and lowering mechanism under push-button control and is fitted with articulated copper blocks in the form of a short endless chain which offers continuous slag support as the machine travels, the copper blocks pressing against the plate, slightly below the seam. The gas shielding is protected against wind dispersal by brushes in contact with the plates. Each welding head is supplied by a welding generator of the normal drooping-characteristic type, giving outputs up to 750 A per head with open-circuit voltages of from 65 to 85 V.

SPLASH AND SPRINKLE –

DRIP AND SPILL



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The machine requires no specialized skill beyond that of any competent welder. Thus, prior to welding, care is taken to ensure that the edges of the plates are reasonably free from scale or rust when set up, and a complete circle of plates is positioned, tacked firmly, and cleated where necessary in precisely the same way as for manual welding. The machine is then lowered into position and adjusted to suit the tank radius. Next, the wire nozzle is positioned at each side, with the slag-supporting chain engaging the plate, after which the welding current for each arc and the traverse speed are set and the starting switch is actuated by the leading operator in the inside cab, striking the first arc and setting the machine in motion. The trailing operator on the outside has the leading weld under observation from the reverse side of the plate and switches in the second arc to fuse with the start of the first weld, subsequent progress then being entirely automatic.

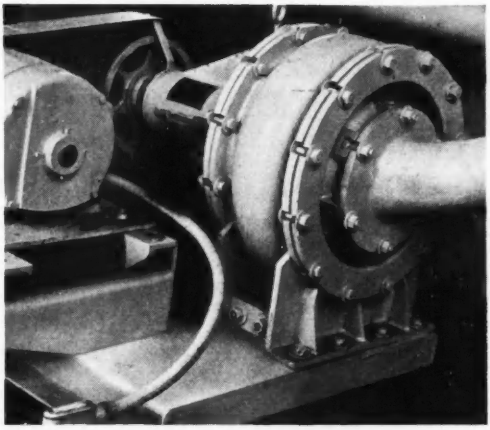
Adjustment of penetration and traverse speed can be made by the operators, if required, while the machine is actually welding. A direct-action control lever enables each operator to keep his arc centralized, if the plate set-up necessitates correction. Because of the deep penetration afforded by the process, no chamfering is needed with plates up to about $\frac{3}{8}$ in. in thickness, and gouging is also unnecessary. A single encirclement of the tank completes welding for plate thicknesses up to $\frac{7}{8}$ in. Multi-pass techniques are used for greater thicknesses.

As a comparison between welding with the "Circomatic" machine and conventional methods, it may be said that, for example, the manual welding of a girth seam for a storage tank about 140 ft in diameter, with plates of from $\frac{3}{4}$ to $\frac{7}{8}$ in. in thickness, would require 300 man-hours, using from four to five operators. On the other hand, with the "Circomatic" process, only two operators would be needed for a period of 5 man-hours actual welding time, plus an extra 20 man-hours approximately for handling and setting up, representing a total of only 30 man-hours.

Non-Clogging "Torque-Flow" Pump

Introduced by the Balfour Group of companies, the new Scott-Wemco "Torque-Flow" pump, can handle, without any possibility of clogging, a wide variety of difficult materials. This pump, which is of American origin and which is made in the U.K. by George Scott and Son (London) Ltd., of Levenbank, Leven, Fife, utilizes a simple but highly effective principle, in which a recessed impeller, located completely out of the flow pattern, imparts a swirling action to the material in transit, causing suction and discharge to become one continuous open passage from the inlet to the outlet flanges. As a result, particles and solids are drawn into the swirling vortex and are discharged with a centrifugal sweep from the open chamber, seldom even touching the impeller. At the same time, the pump is of simple construction permitting quick and easy dismantling and replacement, if necessary.

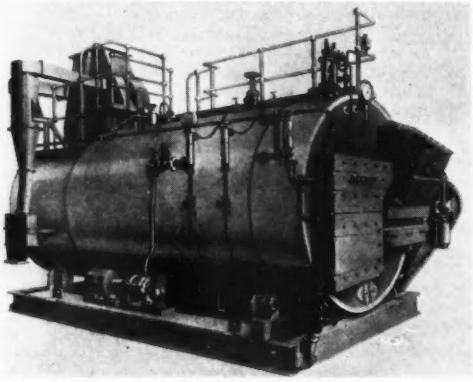
By virtue of this design, the pump can give trouble-free performance with a wide range of materials and requires only a minimum of maintenance. Field tests, covering such applications as the pumping of effluents containing rags, ropes, hair, rubber, wire, and stones, have shown that these materials can be handled without blockage and that the pump will continue to work for



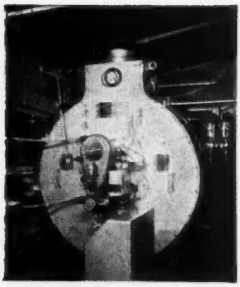
long periods without having to be stripped down for cleaning. Similarly, sludges and slurries with a high content of solids, tough abrasives, and soft, sticky, or fibrous materials can be handled rapidly and efficiently, as also can comparatively fragile substances, since there are no violent directional changes or confined passages in the flow area. Even crystalline slurries can be handled satisfactorily with little or no degradation of the crystals, as the impeller seldom touches the material being pumped. For the same reason, certain fruits and vegetables in a suspension of water have also been pumped without damage for transport from the receiving department to the processing department.

Package-Type Coal-Fired Boilers

The "CoalPak" package-type coal-fired boiler, recently introduced by Davey, Paxman & Co. Ltd., of Colchester, Essex, is a self-contained unit of compact design with remarkably full accessibility. Derived from the well-known Paxman treble-pass "Ultranomic" unit, the new boiler retains all the basic features of the parent



type, included all-welded construction and full-size manholes for internal access and cleaning. The boiler is mounted on its own base and can be seated as a complete unit with a minimum of foundation and installation work. In fact, it is delivered ready for operation, merely requiring connections to the main services.



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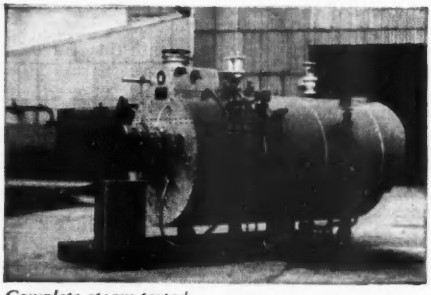
Multipac, backed by over 100 years experience, has many special features and characteristics which, in combination, have led to more and more steam users choosing this boiler.
Its dished-ended wet-back combustion chamber eliminates refractory linings and brickwork. Rapid circulation is obtained because of the 3-pass combustion gas system and its wet-back combustion chamber, giving 82% efficiency. Its quietness cannot be overstressed as a special characteristic; this is why many hospitals use Multipac. Cleaning of the firetubes is only required at very infrequent intervals and easy accessibility is provided. The Multipac is British designed and Clyde built and requires very little floor space, a flat concrete floor is all that is required as a foundation. The standard Multipac is oil fired but another model the Multipac SF is designed for coal firing.



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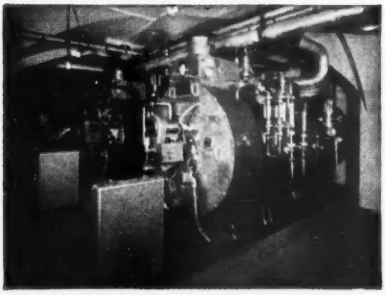
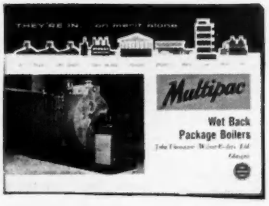


Ashridge College Kent



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These boilers are available in a range of eight sizes, with overall lengths from 17 ft 6 in. to 21 ft 3 in., and with outputs from 2000 to 8500 lb/hr of steam from and at 212° F. The boiler is mechanically fired by a Hodgkinson low-ram coking stoker, the stoker and the induced-draught fan control being modulated in accordance with steam demands. At maximum firing loads, the stoker runs continuously; for partial loads, an automatic turn-down range is provided, giving progressively shorter periods of firing as the load demand is reduced. Automatic coal-feeding to the stoker hopper can be added by the provision of a suitable elevator and, if required, the coal feed to the stoker hopper can also be regulated automatically.

The boiler is lagged and is provided with platforms for access to the major operational points. Adequate safety controls are also provided, the fuel and air supplied being automatically cut off from the boiler and the plant closed down in the event of low water. To meet the requirements of the Clean-Air Act, an efficient dust collector is combined with the induced-draught fan, which is of the cyclone type and which discharges into a hopper at the rear of the boiler.

Simplified High-Accuracy Domestic Water-Meter

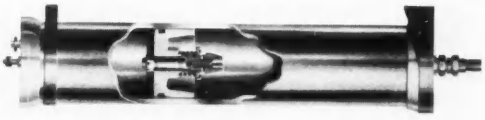
Though of small size and low initial cost, the new type JSM domestic water-meter introduced by George Kent Ltd., of Luton, Beds., is robust and highly accurate and is designed to operate satisfactorily for very long periods under arduous conditions with a minimum of maintenance. The new meter, which has a high nominal capacity, is basically a rotary-piston type, employing the fundamental measuring principle common to many conventional meters and retaining their desirable characteristics, including a high degree of low-flow sensitivity and suitability for installation in horizontal or vertical mains. However, as distinct from conventional meters, its working chamber has its axis in line with the direction of flow, entailing six fewer right-angle changes in fluid-flow direction and substantially reducing flow restriction, with the consequent achievement of an exceptionally compact design, without sacrificing maximum capacity.

The working chamber is contained in one half of the two-section brass body-housing, which consists of two cup-shaped stampings screwed together at their largest diameters and positively sealed with an O-ring. The movement of the working-chamber piston is transmitted to a straight-reading counter by a fully mechanical direct drive, which is part of a combined counter and reduction-gear unit. All gears, etc., are in moulded graphited nylon, reducing friction and wear to a minimum and eliminating corrosion. There is no conventional separate undergear assembly.

The sealed-unit combined counter and reduction gear is another special feature, enabling the usual gland to be eliminated. Contained in the second half of the meter body, it consists of a leakproof transparent-plastic housing, completely filled with a clear liquid, in which the number-rollers, pinion, etc., are immersed, the liquid being both a lubricant and a corrosion inhibitor. This liquid seal provides a complete solution to the problems of counter-gear corrosion and the exclusion of dirt, while the sealed construction of the unit defeats unauthorized interference. The counter housing is automatically compensated against internal or external pressure differences resulting from changes in temperature or hydraulic line pressure. The counter window, in the wall of the meter-body, is reduced in area to the minimum necessary for clarity and is protected by a simple metal flap, providing ready access for reading the counter.

Hydraulic Accumulators

Three new series of hydraulic accumulators have been added to the existing range manufactured by Industrial Hydraulics Limited, of Reading, Berks., i.e., for pressures up to 2000 psi with capacities ranging from 8 to 20 gal, for pressures up to 5000 psi (1 to 8 gal), and for pressures up to 5000 psi (8 to 20 gal). All these accumulators are of screwed end construction and incorporate safety interlocks to prevent the unit from being dismantled whilst under internal pressure. Various port sizes and flanges are available.



These accumulators embody a patented liquid-seal piston assembly, specially designed to overcome one of the main problems encountered with all gas-loaded piston separator-type accumulators, i.e., that of sealing the gas charge when the hydraulic system is shut down. During shut-down, the hydraulic system is under atmospheric pressure only, and hitherto it has been found difficult to prevent the high-pressure gas charge from leaking into it. The special feature of the liquid-seal type of accumulator is a probe which seals the oil outlet of the accumulator when it is discharged. In this way, the problem is made much simpler and merely becomes one of retaining oil under a lower differential pressure. Should there be any leakage, due perhaps to deterioration of the piston seal after prolonged usage, this would be of oil into the gas chamber, rather than the troublesome one of gas into the hydraulic system.

A new Grommet development

THE DOUBLE SEALING EMPIRE RUBBER GROMMET

infinitely accommodating in use: considerably reduces range of sizes because the same grommet can be used with several plate thicknesses or cable sizes

PAT. APP. No. 5255/59

This newly developed self-conforming grommet, because it is immediately self-locking against the elements, is the solution to many of an engineer's sealing problems.
Any one size will not only accommodate itself to a variety of mounting plate thicknesses, but (designed for cable or control rod) will take these in a variety of sizes and be weather-, water- and dust-proof at a variety of angles to the cable or rod.

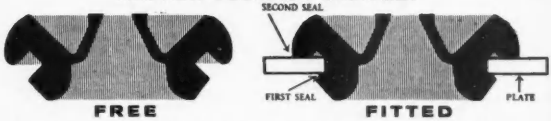
Because of its capacity to conform to many varying requirements, it enables a workshop stock range of grommets to be reduced to perhaps one tenth of that at present maintained.

THE NEW BLIND GROMMET

FREE

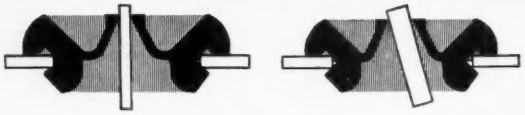
Note how when sprung into position the grommet provides a perfect double seal by its own permanent pressures. The angled groove also creates a tight pressure hold on the metal plate.

THE NEW DESIGNED GROMMET

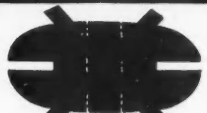


FREE FITTED

In the cable grommet variety the same double pressure seal is created, allied to tight seal on various diameters of cable. This new grommet gives sound sealing at *all* vital points.



A useful feature of this cable grommet is that by reason of the designed taper of the cable entry and the flexibility of the web, a considerable angle of cable entry and a variety of cable size are possible. This avoids necessity for special grommets with angled bores.



In the conventional grommet, only one thickness of plate and only one size of cable can be accommodated. No effective seal is afforded by the parallel groove.

Now being produced in a range of sizes.

THESE GROMMETS WILL SOLVE YOUR SEALING PROBLEMS.

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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Turbulent Lubrication

By V. N. CONSTANTINESCU

From an advance copy of a paper received from *The Institution of Mechanical Engineers*, London, May 1960, 18 pages, 18 illustrations.

THE motion in a lubricant layer is generally considered as laminar, owing to the thinness of the layer, and consequently, under usual conditions, the Reynolds number of the flow has relatively small values. Recently, however, the problem of journal bearings at turbulent speeds and, of course, the study of turbulent lubrication present a special interest, with the continuing trend in machine design towards higher speeds and also because of the use of lubricants other than oils, having a smaller viscosity.

It may be considered, as a general phenomenon, that by increasing the Reynolds number of the lubricant flow, the laminar motion breaks down into a turbulent motion. In ordinary conditions, the corresponding critical speed for water bearings is of the order 2000 rpm for oil bearings 20,000 rmp and for gas bearings 100,000 rpm. These speeds are high enough, but are comparable with the speeds used in some modern machines.

In order to determine the velocity profile and the pressure distribution in the bearings, this paper contains a theoretical study of the motion in the lubricant layer, considering it as having a turbulent character. Proceeding from the Reynolds equations and introducing the approximations currently used in lubrication problems, owing to the lubricant film thickness, the general-motion equations for turbulent lubrication are given. Using the Prandtl mixing-length hypothesis, exact and approximate solutions are obtained for the velocity distribution into the lubricant layer, the results being discussed by pointing out the pressure gradient and the Reynolds-number influence on the velocity distributions, as well as the differences with respect to the laminar flow.

In order to obtain simple formulae, the exact dependence of the rate of flow on the pressure gradient into a dimensionless form is replaced by a linear relation, the slope of which depends on the Reynolds number. This approximation makes it possible to obtain the pressure-differential equation under a simple form. The pressure equation is integrated in the case of journal bearing by assuming a constant or a variable lubricant viscosity.

By means of the continuity equation, the pressure equation can be written both for variable and constant viscosity. This equation has a similar structure to that obtained for laminar flow and consequently may be integrated by using a similar procedure. Explicit formulae are thereby obtained for calculating the pressure distribution and the pressure resultant. The load-carrying capacity of the bearing is, in turbulent flow, substantially greater than in laminar flow, and the difference increases as the Reynolds number.

Experience with a Tapered-Shaft Cupola Furnace

By A. A. CHERNY and E. D. SOSNOVSKY

From *Liteinoye Proizvodstvo*, Russia, No. 4, April 1960, pp. 13-15, 2 illustrations.

IN recent years, various methods have been suggested for improving the performance of cupola furnaces, the use of preheated or oxygen-enriched blast and the application of water-cooled shells being some of the most promising lines of progress. An interesting approach to modernizing the cupola furnace has been made in a Russian plant, and this article summarizes the results from 305 melts obtained with a specially constructed tapered-shaft cupola furnace which is claimed to achieve substantial economy in fuel and refractories, to eliminate burden hanging, and to reduce scrap.

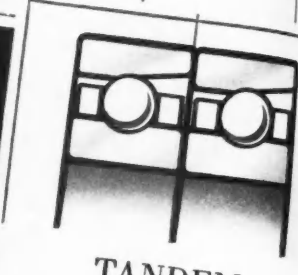
Initially, the furnace was designed with a maximum external diameter at the melting zone of 2 m, and a corresponding internal diameter of 1·3 m, but in actual practice it was found necessary to reduce these dimensions to 1·8 and 1·2 m respectively. The total height of the furnace is 4·95 m, the integral diameter at the tuyeres and at the throat is 90 cm, the conical section of the shaft above the melting zone having a taper of 10 : 1. The tapered shaft was constructed by laying refractory bricks vertically inside the shell in a step-wise manner, so as to approximate the theoretical contour. In actual fact, the true conical shape of the shaft was achieved only after the first few melts, when the protruding edges of the bricks burned off. It was found that, with this type of construction, the lining did not fuse to more than 10 mm in depth, and larger cavities occurred only near the tuyeres. In general, the wear of the furnace lining was found to be superior to that of a conventional furnace, this being mainly attributed to the conical shape of the shaft, which provided a smoother flow for the gases and prevented local damage to the refractories.

During experimental investigations into the optimum operational parameters of the furnace, the metal charge was varied from 650 to 1000 kg, the coke charge from 80 to 120 kg, and the coke size from 70 to 150 mm, at a maximum temperature of the melt of about 1420°C. It was found that the average output of the cupola furnace under these conditions varied from 7·3 to 10·5 tons per hour, optimum results being achieved with a cold metal charge of 1000 kg, with a corresponding coke charge of 120 kg, and a coke size of 70 to 120 mm. The blast pressure of the furnace for most of the melts was about 900 mm w.g., and the air consumption about 160 m^3/min. The furnace also operated satisfactorily

SUPER-PRECISION ANGULAR CONTACT

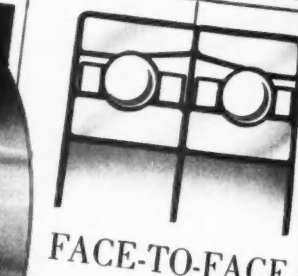
BACK-TO-BACK

(VM)



TANDEM

(VF)



FACE-TO-FACE

(VH)

These FBC bearings were originally developed for use in high-speed machine tools; their use has since spread to instruments, turbines, compressors and other precision applications.

There are three precision grades—5, 7 and 9: in grade 5 the tolerances for the bore range from 2-ten/thousandths of an inch* in the small sizes to 3-tenths in the large. The outside diameters range from 2-tenths tolerance in the small sizes to 5 in the largest, with corresponding accuracy in other dimensions. Grades 5 and 7 bearings meet the majority of precision applications but grade 9 bearings are also available for hypercritical uses.

For example, a grade 9 bearing of 30 mm bore has one-tenth tolerance in the bore and 1½-tenths in the O.D., one-tenth track eccentricity and track wobble; with parallelism tolerance on faces, and out of square of ½ a-tenth. These bearings are generally used as follows, the standard bearings needing no selection for pairing:—

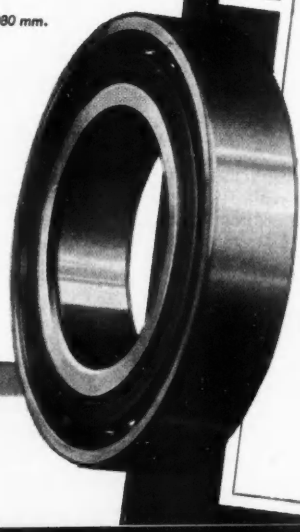
BACK-TO-BACK MOUNTING, giving greatest rigidity, automatically pre-loaded when locked up on shaft.

TANDEM PAIRING, as often used in high-speed precision grinding spindles, with one pair spring-loaded axially.

FACE-TO-FACE PAIRING, giving suitable pre-loading with outer races locked up.

We are always ready to advise on the application of these and other FBC bearings, from our long and varied experience.

** ½ a tenth: .001270 mm. 1½ tenths: .003810 mm. 2 tenths: .005080 mm. 3 tenths: .007620 mm. 5 tenths: .012700 mm.*



F·B·C

BEARINGS

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FAFNIR BEARING COMPANY LTD.
(successors to FISCHER BEARINGS COMPANY LTD.)
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at lower pressures (about 500 to 600 mm w.g.), but the output was reduced to about 6·5 to 7 tons per hour.

A further feature of the furnace was the use of four additional tuyeres, 90 mm in diameter, for the injection of oxygen or compressed air above the melting zone. When compressed air was blown in at a pressure of 4 atm for 2 hr, the melting time could be decreased, but the slag contained an extremely large percentage of iron oxides. When blowing oxygen at a pressure of 1 to 1·5 atm, the iron oxide content of the slag was insignificant, the temperature of the melt increased, and productivity improved by about 30%. The average oxygen consumption was about 12 m^3 per ton of hot metal, or 72 m^3 per hour. It was also established that oxygen-blowing is most beneficial when the furnace is fully charged.

The Influence of Exhaust-Belt Design on the Discharge Process in Two-Stroke Engines

By R. S. Benson

From an advance copy of a paper received from *The Institution of Mechanical Engineers*, London, June 1960, 18 pages, 17 illustrations.

In a previous paper by the author, experimental results were given for the discharge from an engine cylinder direct to atmosphere. Design methods were developed for this case and data were produced for facilitating exhaust-port calculations. In practice, the gas will be discharged from the cylinder through a belt and pipe to atmosphere, and the discharge time will be influenced by the belt design and the pipe dimensions. The effect of pipe length and bore can be computed, but the influence of belt design is not readily amenable to calculation. There has been very little published work on belt design and its influence on the discharge process. Since it is desirable to obtain the maximum flow through the exhaust ports and since the exhaust belt can mar a good port design, it is considered that a systematic study of exhaust-belt design should be carried out.

In a multi-cylinder two-stroke engine with exhaust ports all around the liner and with the exhaust pipe or pipes on one side of the engine, the exhaust-belt design is controlled by the distance between the cylinder centres and the main-bearing size, or in an opposed-piston engine by the distance between the tie-rods. This, in general, leads to a complex design, and simple one-dimensional flow theories cannot adequately describe the flow from the belt to the pipe, although they may be used as a basis for design calculations. In order to ascertain the influence of the belt shape on the pressure conditions at the entry to the pipe, it is necessary to carry out experimental investigations.

In this paper, details are given of a comprehensive investigation into the influence of belt design on the discharge process of a two-stroke engine. Theoretical methods are developed for calculating the pressure changes in the cylinder, exhaust belt, and pipe, and a detailed experimental investigation of ten exhaust-belt configurations is described. Pressure measurements were taken in the cylinder, belt, and pipe, and showed that the pressure was not uniform within the belt and decreased from the belt to the pipe. It has been found that an increase in belt size reduces the restrictive effects of a belt, shortens the blow-down time, and increases the pulse amplitude in the exhaust pipe. There is an optimum belt size, above which no further improvement is obtained, unless the belt profile is altered; at this size, the belt can be made within the normal engine dimensional limits. Data are given for designing exhaust ports and belts based on these experiments, together with the detailed development of the boundary equations for the gas-exchange process.

Multiple-Brazing Processes

By G. D. Cremer and R. S. Mueller

From *Welding Journal*, U.S.A., Vol. 39, No. 6, June 1960, pp. 592-599, 11 illustrations.

One post-war technique which has advanced rapidly and which continues to show an amazing growth potential is high-temperature corrosion-resistant brazing, one application of which is multiple brazing. High-temperature corrosion-resistant brazing is a metallurgical joining process employing a molten filler metal which has a melting point in excess of 1600°F but below that of the base metal. Atomic diffusion between filler metal and base metal must occur.

Multiple-brazing processes (occasionally referred to as "double brazing") utilize two, three, or sometimes more separate and distinct brazing operations. During each brazing cycle, new components or sub-assemblies are added in building up the final structure. With this technique, extremely complex, dimensionally stable, lightweight structures are being manufactured.

Numerous successful applications have demonstrated the advantages and remarkable versatility of the high-temperature corrosion-resistant brazing process. Multiple brazing not only incorporates all of these advantages, but also provides opportunities for increased production control and manufacturing economy. By using brazed sub-assemblies or a sequence of brazing operations in building up a metal assembly, several manufacturing advantages are obtained.

In this paper, emphasis is laid only on metal structures joined by corrosion-resistant brazing alloys of the nickel-base type, and examples are given of typical multiple-brazing applications which are now being exploited commercially on a large scale, including the brazing of gas-turbine diaphragms and honeycomb seals, honeycomb fuselage sections, nose and tail cones, air ducting, afterburner heat shrouds, and honeycomb-panel wedge-shaped or tapered structures and panels.

A useful development that has shown great production significance for multiple-brazing processes has been dubbed the "*in situ*" technique. To date, the method has been applicable only to joints where a brazing-alloy powder is used. A sintered form or insert, however, may

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offer additional design latitude. By mechanically mixing a selected metal powder with the brazing-alloy powder, it is possible to produce brazed joints with special characteristics, the principle involved being to effect braze diffusion *in situ*. Thus, when the braze metal flows, it immediately wets and begins to alloy with the refractory powder filler, as well as with the base metal of the joint itself. Rapid diffusion between the braze and filler occurs, owing to the large interfacial surface area involved. This desirable metallurgical phenomenon and the sponge-like nature of the undissolved filler hold the braze in place and effectively prevent flow-out. Only a small amount of braze metal fills the actual joint faying-surface volume, the bulk remaining where originally applied in the fillet areas. It should be noted, however, that the *in situ* technique requires an increased understanding of non-equilibrium metallurgy and diffusion kinetics. Its potential application is great, but brazing metallurgists must supply the answers for its practical utilization.

Changes in the Surfaces of Mild-Steel Specimens during Fatigue Stressing

By G. F. Modlen and G. C. Smith

From *Journal of the Iron and Steel Institute*, London, Vol. 194, Part 4, April 1960, pp. 459-464, 8 illustrations.

It has long been recognized that fatigue damage takes place by a gradual process and is not confined to the last portion of the test. In the work reported in this paper, corroborative evidence that this damage is associated with surface cracks propagating into the material, rather than with any form of work-hardening, has been obtained in four ways. Thus, if cracks are present only in the surface of a specimen, then testpieces machined from the interior of fatigued specimens should be unimpaired in their resistance to subsequent fatigue stressing. Similarly, interrupting a test to remove the surface by grinding or by some other means should make it possible to prolong the test indefinitely. Intermediate annealing can be expected to have little effect upon subsequent resistance to fatigue stressing, since microcracks, rather than any form of work-hardening, are thought to constitute fatigue damage, and these would remain unchanged under this treatment. Finally, metallographic evidence has been obtained which indicates that the sites of eventual cracks may be identified after the first 10% of the fatigue test.

The conclusions derived from this investigation can be summed up as follows:—

(1) The interiors of specimens subjected to fatigue do not suffer damage with respect to subsequent fatigue testing.

(2) It is possible to prolong the endurance of testpieces by removing the surface layers to which cracking is confined, and the depth that has to be removed after a certain number of cycles to produce this effect increases as the number of cycles increases.

(3) Resoftening is not effective in eliminating the deleterious effects of fatigue stressing.

(4) Metallographic examination shows that persistent slip lines may be found in mild steel. There is also evidence of the existence of persistent slip bands under repeated compression loading.

An Experimental Investigation into Radial Thrust in Centrifugal Pumps

By A. Agostinelli, D. Nobles, and C. R. Mockridge

From *Transactions of the ASME Journal of Engineering for Power*, U.S.A., Vol. 82, Series A, No. 2, April 1960, pp. 120-126, 11 illustrations.

Among other problems with which designers of centrifugal pumps must cope is the unbalanced load on the impeller caused by non-uniformity of the static pressures and velocities within a volute, particularly under off-design conditions. Unless shaft and bearing designs are modified to compensate for higher loads, the resultant shaft deflection due to this radial load can sometimes be of sufficient magnitude to cause rubbing at close running clearances, resulting in premature wear on the parts in contact. Furthermore, the load is cyclic because of rotation and can lead to shaft failure as a consequence of fatigue. It is therefore important that the radial forces acting on the impeller be given consideration in the mechanical design of a centrifugal pump.

It is surprising that there is relatively little published technical information on radial thrust, since its presence in centrifugal pumps and its significance on pump performance have long been known. It is therefore the object of the experimental investigation described in this paper to determine the magnitudes and directions of the unbalanced radial forces on centrifugal-pump impellers. The work has been confined to single-stage units pumping water, the objectives of the experimental programme being to determine the effect of specific speed and casing geometry on the developed radial forces for the complete operating range of the pumps. Measurements of the magnitude and direction of the resultant radial thrust have been made on conventionally designed volute pumps covering a wide range of specific speeds, on double-volute collectors, concentric casings, and on modifications of the concentric design, and the results are presented in graphical form.

In addition, details are given of a radial-force measuring system, which makes use of strain-gauges and which was developed and employed for this test work. This system has so greatly facilitated the determination of unbalanced radial forces that it has become a part of the rating tests for new pump designs.

The test results indicate that there are certain characteristics of radial thrust in volute pumps which appear to vary with specific speed, these being the fraction of design capacity at which the minimum thrust occurs, the range of capacity over which the forces are close to minimum, the direction of the resultant radial forces, and the radial thrust factor, which is a parameter varying with capacity. In addition, it has been found that concentric casings with certain dimensions of width and diameter are quite effective in minimizing the unbalanced radial force on a centrifugal-pump impeller.

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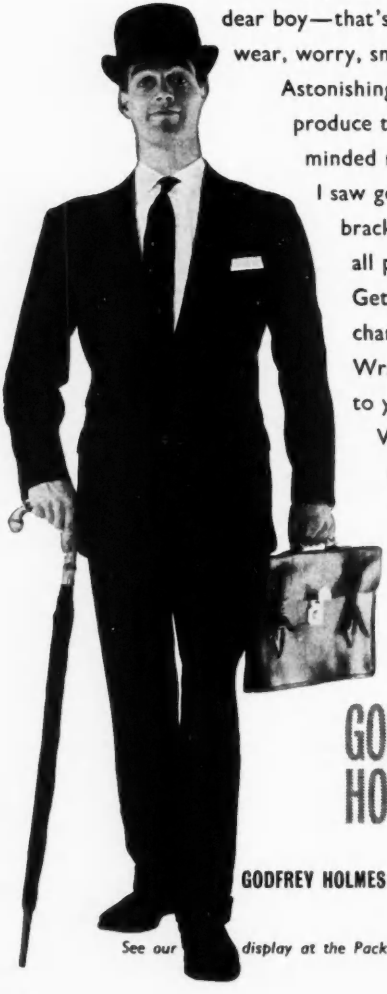

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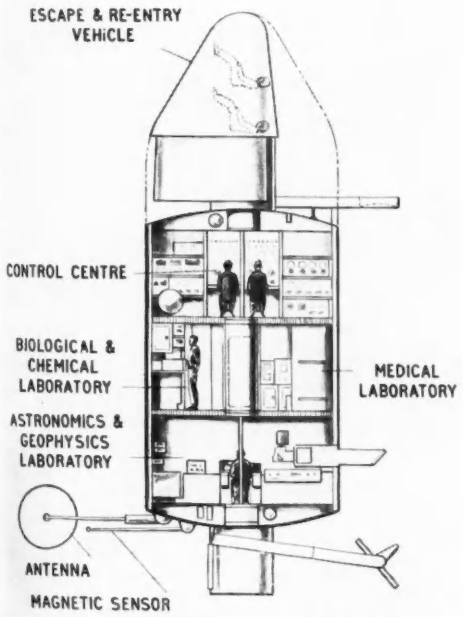
Proposed Design of Manned Space-Satellite Laboratory

Described as a technically feasible second-generation space vehicle, providing a necessary link between current U.S. astronautical programmes and the more ambitious space vehicles of the future, a design of manned space-satellite laboratory, to be put into orbit by 1965, has been outlined by the Baltimore Division of the Martin Company. It is stated that this concept is based entirely on currently known technology and is not predicated on any as yet unknown or tentative developments in materials or in propulsion and guidance systems.



Essentially, the laboratory would comprise a 16-ton pre-assembled unit capable of carrying from four to six men, boosted into a one-year orbit by a three-stage rocket of the three-stage "Saturn" class. The orbital altitude would be 400 miles, so as to avoid the hazardous radiation effects of higher altitudes. Although basically intended for conducting scientific experiments and other tests of equipment, materials, and concepts for human survival and activity in space, the laboratory could also serve as a vehicle for manned reconnaissance of the moon between 1965 and 1968.

A feature of the design is that the laboratory could be operated without any provision for rotation in space, i.e., for artificial gravity, and without any need for any as yet unproven ecological system for life support. Furthermore, personnel in the laboratory would not require elaborate space suits (though space-suit tests might be conducted as part of the overall experiments), but could live and perform their duties in a true "shirt-sleeve" environment. The laboratory crews would operate the station for from two to four weeks at a time and would then be replaced by other crews sent up in rendezvous vehicles, which could be launched by advanced intercontinental ballistic-missile boosters now programmed and which could bring food, equipment, and supplies, as well as personnel. These vehicles would remain attached to the orbiting laboratory during each tour of duty.

The laboratory itself would be a double-shell, three-compartment cylinder with convex end-domes. The beryllium outer shell would serve as a meteroidal bumper and thermal shield, while the aluminium-alloy inner wall would serve as the vehicle load-carrying component and sealed-cabin pressurized container. The three compartments would be separated by aluminium-alloy honeycomb bulkheads with airlocks, with cylindrical airlocks at each end of the vehicle for ingress and egress and also to serve as space-environment test chambers. Cabin atmosphere would be supplied by liquid oxygen and nitrogen. Air-conditioning units (one per chamber) would continuously circulate air at 70° F. An automatic wall heat-distribution system, using water-filled tubes attached to and encircling the cabin wall, would require approximately 350 lb of water, 275 lb of hardware, and 500 W of power. The water reservoirs would also serve as heat sinks for the air conditioners.

New Winding Design for Two-Speed Electric Motors

Development by Associated Electrical Industries Ltd., based on the results of investigstions by Professor G. H. Rawcliffe, of Bristol University, has produced a design of two-speed electric motor which is not only smaller than conventional machines of similar rating but (especially in the case of more powerful machines) also lower in price.

Where the duties of an induction motor require more than one speed, in a ratio other than 2 : 1, it has been the practice to use two stator windings—a convenient arrangement, but one which involves increasing the size and weight of the motor. Professor Rawcliffe's work, however, has shown that, with pole-amplitude modulation, a motor with a single winding can run at two speeds with a ratio of less than 1·5 : 1 (e.g., with pole numbers such as 6/8, 8/10, 10/12, etc.), and a range of motors built to this design has been tested at Bristol University, in A.E.I. factories, and elsewhere.

In the A.E.I. factory at Rugby, a change-pole squirrel-cage motor rated at 800 hp, 750 rpm, and 450 hp, 600 rpm, designed to drive an induced-draught fan in a power station, was recently modified by the substitu-

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tion of a single stator winding for its two independent windings. No other changes were made, except for the provision of a new stator core to accommodate the winding. It was found that the modified machine could be comfortably housed in a smaller frame, and, in fact, a smaller frame would be used for a motor of this rating designed in the first place with a single winding. The performance of this motor is substantially the same as that of equivalent double-winding machines.

By using fractional-slot windings, A.E.I. have evolved an alternative to the Rawcliffe system, in which 1·5 : 1 is no longer the upper limit of the speed ratios available. Although this method requires the use of more leads and more switching than pole-amplitude modulation, it gives the designer greater freedom in matching the characteristics of the motor to the load. It also involves extensive calculations, which at Rugby are done on a digital computer.

As a result, A.E.I. is now offering machines with following pole numbers of 6/8, 8/10, 10/12, 12/14, 14/16, and upwards, where the difference in pole numbers is two. In these cases, there are six brought-out leads and a simple switching arrangement. Machines with multiples of the above ratios will also be supplied (e.g 12/16, 16/20), with similar leads and switching arrangement. With additional switching, machines with other speed ratios can be supplied, and, where three or four speeds are required, change-pole machines with two stator windings will be available.

Ball-Type Blocks for Supporting Cylindrical Components

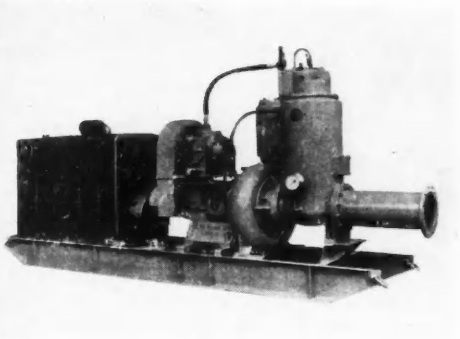
Eliminating the drawbacks of conventional Vee-blocks, which can only be as accurate as the machining methods employed to produce them, the new Rubert "B" blocks announced by Rubert & Co. Ltd., of Cheadle, Cheshire, are a new design of supporting stand for cylindrical components, in which only the top and bottom faces need to be accurately machined, the component being supported on four hardened and polished steel balls positively located on the top surface. As a result of this reduction in machining requirements and the inherent accuracy of commercially manufactured steel balls, the new stand, despite its accuracy of ±0·0001 in., can be offered at a very competitive price. For high-precision work calling for stands of higher accuracy, special models can be supplied to order.

It is true that concentricity equipment using balls for supporting a component has been available for some time, but this equipment employs two adjustable balls only, so that time must be spent in setting up with a test-bar each time it is used. In the new "B" blocks, however, the four balls, which are locked together on a flat surface, are precisely self-locating by virtue of their own extreme accuracy, so that the component becomes self-aligning by providing four contact points on each block. In addition to its self-aligning properties, this four-point support minimizes the chances of marking even when the component is being rotated. When carrying a very heavy component, accurately made shims are avilable to spread the load and, for very soft metals, nylon balls can be fitted in place of steel balls. As each pair of balls is unequally spaced, two different angles are provided for cases where "lobing" is suspected. Should wear eventually take place, the balls can easily and quickly be unlocked and rotated to provide new contact points.

It is possible for the same pair of "B" blocks to accommodate diameters from $\frac{1}{64}$ to 10 in. merely by turning the blocks through 90 deg. For inspection purposes, provision is made for clamping, clamps being available for the full range of diameters which can be accommodated. The standard model is intended for use in the upright position, but a further model is available, with the side faces accurately finished in terms of squareness and flatness, enabling it to be used on any side, as well as in the upright position.

Unchokeable Centrifugal Pumps

The latest addition to the range of "Univac" centrifugal pumps produced by Henry Sykes Ltd., of London, S.E.1, is the UVS12, a 12-in. unit capable of delivering 3500 gpm against a total head from all causes of 32 ft. Particular features of the "Univac" pump, of which the UVS12 is the largest in the range, are the unchokeable and extremely rapid priming effects achieved by providing a separate vacuum pump to evacuate any air which may have become entrained in the pump body; as a result, the impeller and volute have been designed purely for pumping duties, as distinct from the normal compromise in self-priming centrifugal pumps, where the self-priming and pumping duties are combined, with a resulting loss in efficiency.



The major components of the pump are the twin-cylinder, horizontal, air-cooled vacuum pump, mounted for direct drive off the engine shaft, the "Univac" self-priming equipment, mounted on the suction side of the pump, the high-efficiency centrifugal pump, and a reflux box on the delivery side of the pump. The "Univac" equipment consists of two tanks, a primary and a secondary, the height of which is appreciably above the level of the centrifugal-pump chamber. The primary tank, which contains a float for actuating a piston and valve through a valve holder and rubber buffer, is connected to the secondary tank, equipped with a ball valve and rubber seating, the outlet from this tank being the inlet to the vacuum pump. As the level of this equipment is above that of the centrifugal pump chamber and precedes it in the suction line, any air being drawn into the suction is released into the primary tank and therefore does not pass into the pump chamber, whilst, on priming the pump, any air contained in the pump chamber is drawn up into the primary tank. In addition, the secondary tank prevents water from reaching the vacuum pump.

The pump can handle large solids and abrasive sludges of up to 60% solid content, the nature of the material handled in no way affecting operation of the

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"Univac" equipment. Whilst the design of the equipment makes the pump particularly suitable for operating where large volumes of air may be encountered as a result of variations in the suction, as in tunnel-driving and in many chemical and process works, it is also useful where large volumes of water are required to be pumped and where no loss of priming can be tolerated.

Four-Channel Spot-Welder Control

Suitable for use with any spot or projection welder, the new "Synchrospot" four-channel spot-welder control announced by Sciaky Welding Machines Ltd., of Slough, Bucks., is stated to eliminate transients and hence to reduce power demands considerably. Furthermore, the duty cycle is improved and electrode-tip life is considerably extended, while indentation, burning, and marking of material are greatly reduced.

The unit is essentially a completely self-contained control for single-weld or automatic continuous operation, and comprises a 4-stage dekatron timer and an ignition contactor, all housed in a strong cabinet occupying a floor space of only 12 × 18 in. and so designed that it is suitable for static or portable machines or for wall or floor mounting. In addition, phase-shift heat control, usually an optional extra on this type of equipment, is a built-in feature of the "Synchrospot", and eliminates tap changing, as well as enabling critical weld settings to be obtained.

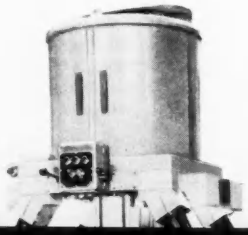
The dekatron timer and the heat control are each contained in a separate chassis, mounted on slides for easy removal, with all connections made through plugs and sockets. Controls permit four synchronous time ranges of from 1 to 90 cycles each for "squeeze", "weld", "hold", and "off". All control dials and switches are visible through a perspex window, with a separate lock for the use of the setter, while the ignitrons and main connections are protected by a locked door for the use of maintenance personnel. With this control it is possible to permit welds at speeds in excess of 750 spots per minute and, even at these high speeds, each weld time can be guaranteed to be 100% accurate.

Transistorized Portable Multi-Purpose Measuring Instrument

Fully transistorized and employing a printed circuit, the "Elcotector Mark II" is a portable instrument designed to carry out a wide variety of measurements in a non-destructive manner. The instrument, which can be used anywhere in the factory or in the field, is made by the East Lancashire Chemical Co. Ltd., of Fairfield, Manchester, and is a development of their well-known mains model.

The primary objective of the new portable instrument is for all types of coating measurements on components. In addition, it is capable of measuring the thicknesses of most metallic and non-metallic foils both in the static and the moving state, so that it can be applied to a production run to give continuous ratings of thickness, hardness, or other changes. Other duties include its use in crack detection, in comparing the hardness of steel components, and in detecting variations between different types of alloys, etc.

The instrument operates on the principle that the electrical characteristics of a coil are influenced in proportion to its proximity to a metal surface, and under suitable conditions a meter is capable of translating these changes in the coil into the measurement of non-metallic coatings on metal. This coil is also influenced by the type and structure of the metal, so that these changes can be translated into metal film thickness, metal hardness, and like measurements. The coil in the case of the instrument is situated in the head of the probe presented to the surface under test. Two types of probe are available, one being in the form of a short pencil for general purposes, while the other has a small head and angular extension to enable it to be used in narrow confined spaces. These two probes are used for manual checking purposes only, but, for continuous strip measurement, special probes can be produced capable of accommodation on any specific machine. Hollow cup or pot coils are available for repetitive hardness measurements of items such as drills, plug gauges, taps, and steel balls.



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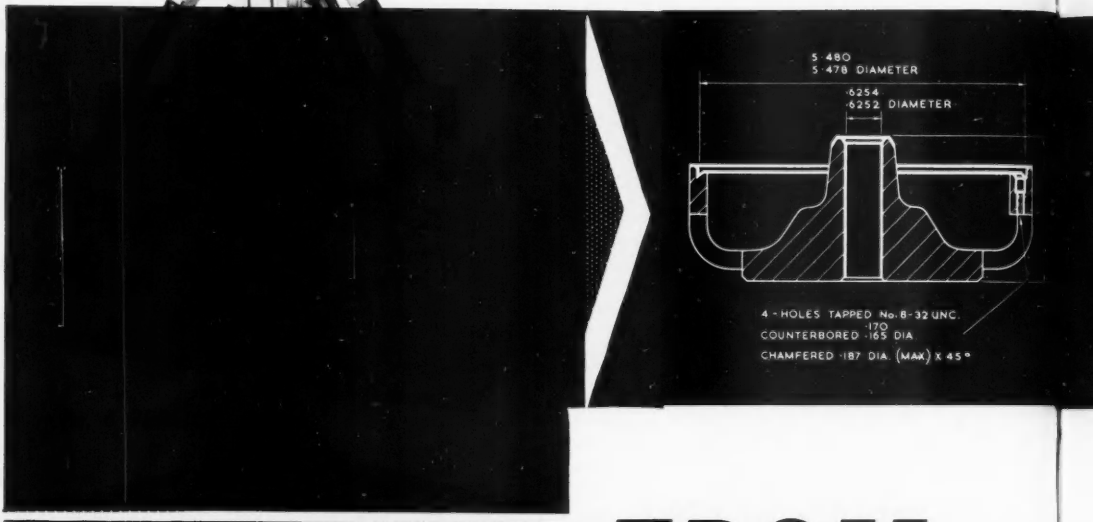

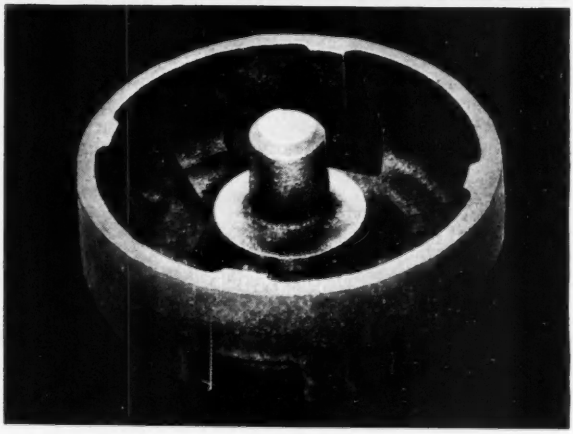

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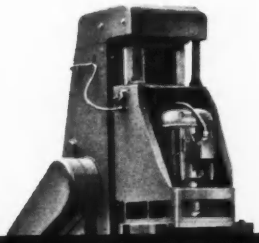

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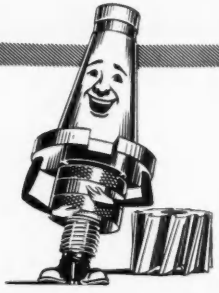
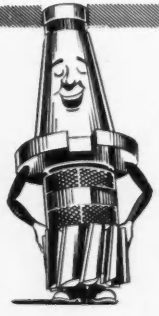


Second Stage

Screw on the cutter to meet the nut—then release by a part reverse turn.



Third Stage

Screw back the nut firmly against the cutter by hand—immediately cutting starts the cutter will lock solidly against the nut, making a rigid tool assembly.

To Release

Apply the spanner to the nut and a few sharp hammer blows will release the nut from the cutter, which can then be screwed off by hand."

You can't go wrong—send for the Heli-Matic brochure giving the full range of Arbors and Cutters.

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THE SHEFFIELD TWIST DRILL AND STEEL COMPANY LIMITED
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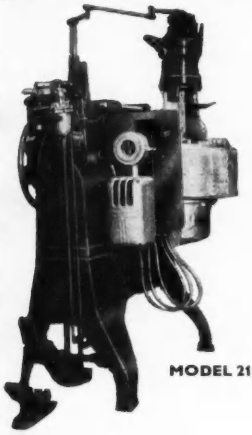

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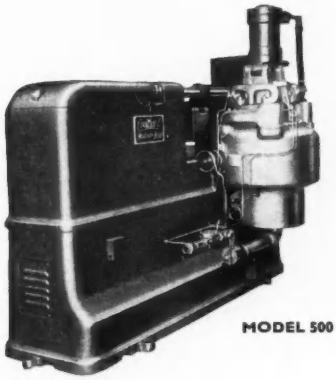

MODEL 500

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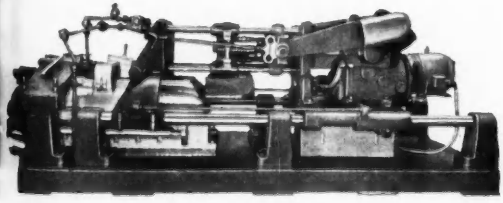

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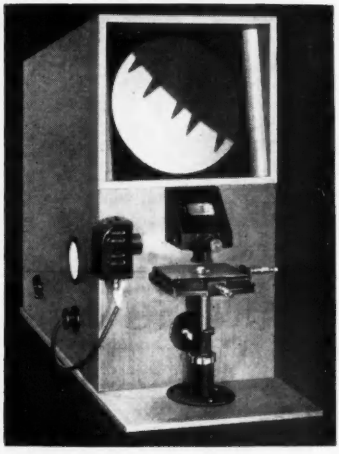
Enbeeco Profile Projectors



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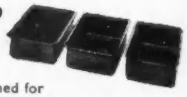

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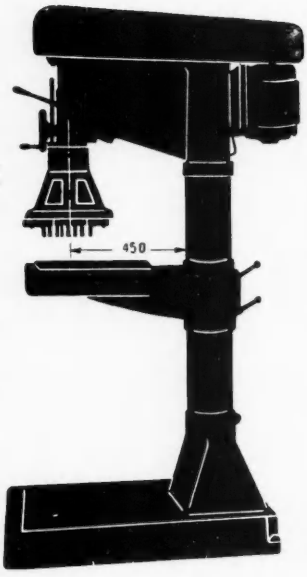

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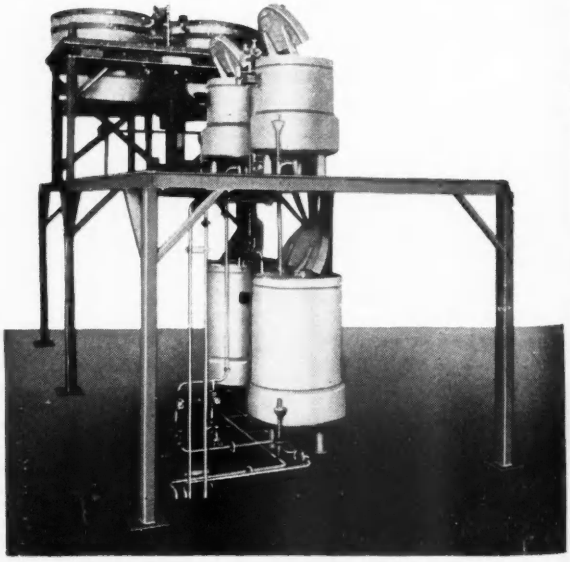

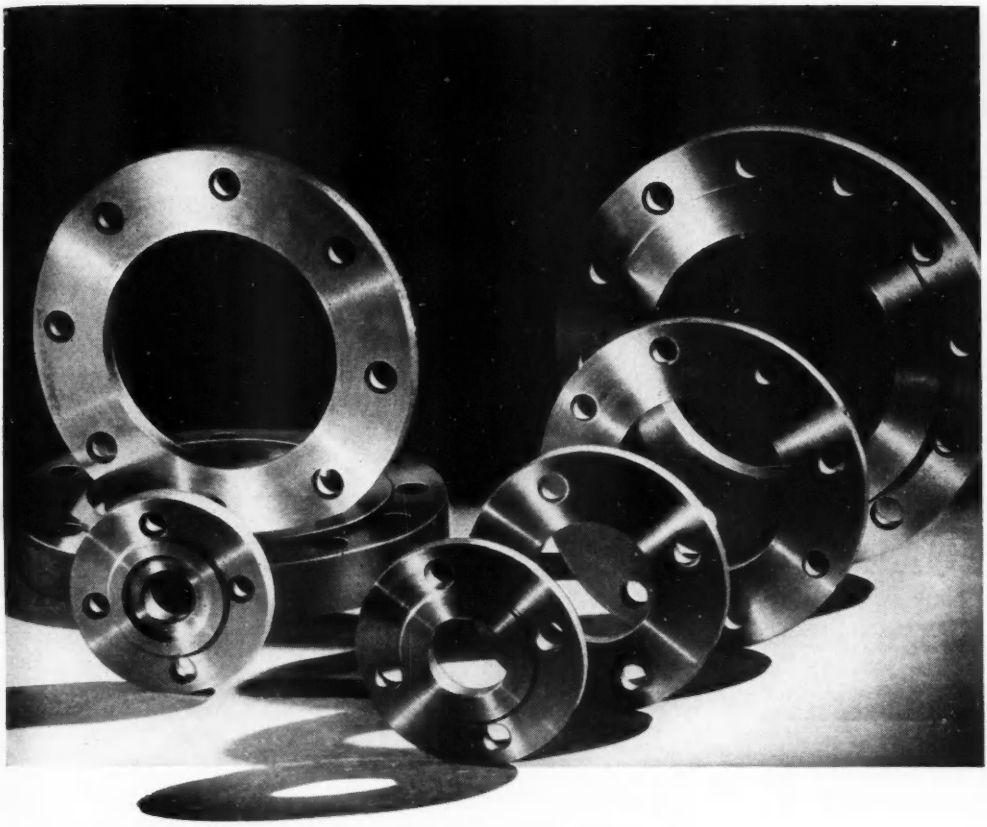

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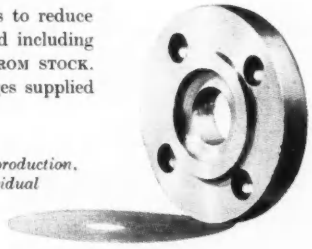

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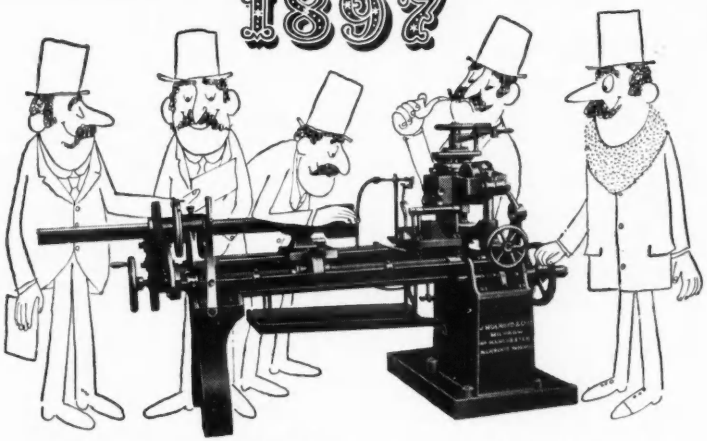

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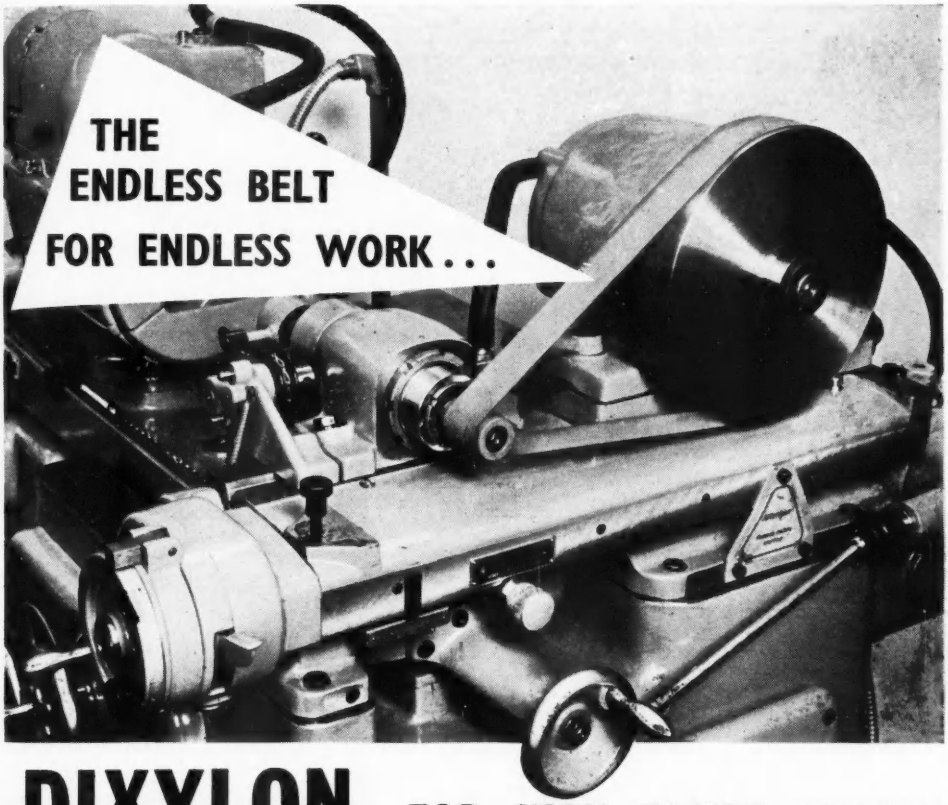

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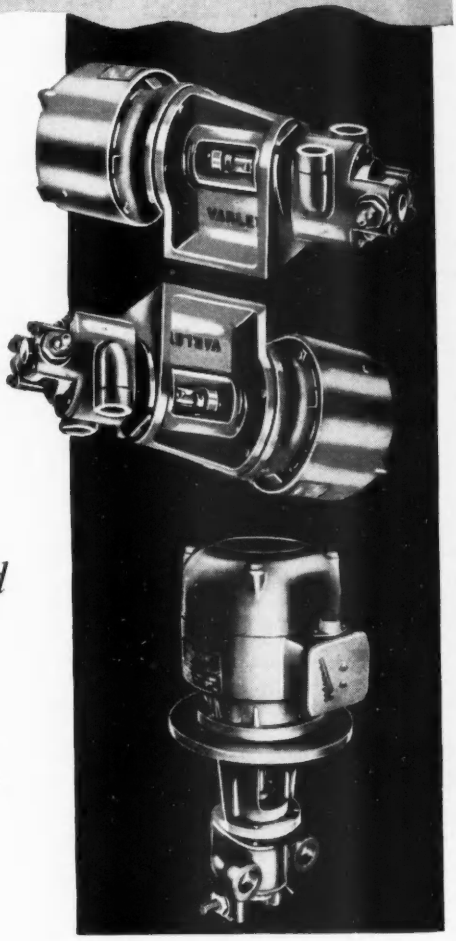

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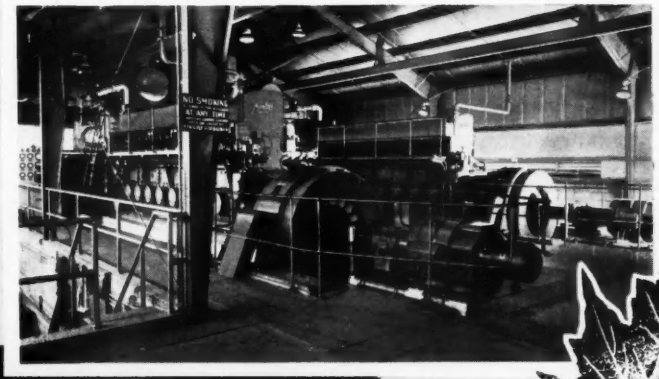

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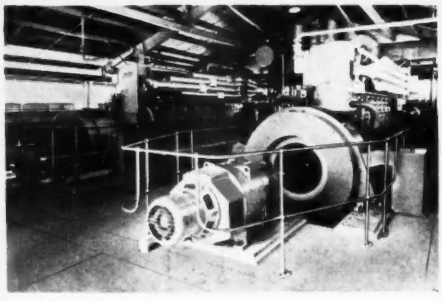

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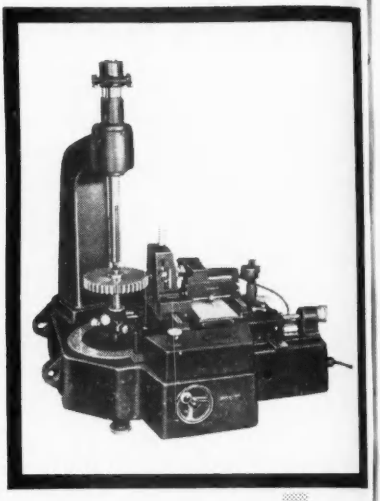

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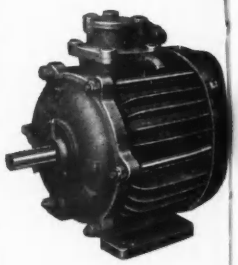

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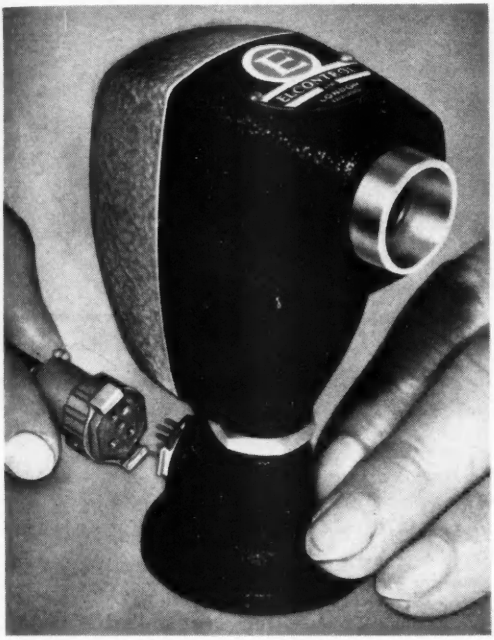

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PR6 **Photorelay,** *for general photoelectric control—only 7½″ × 5¾″ × 5″.*

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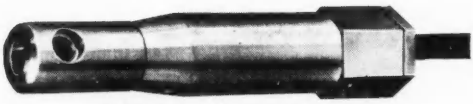

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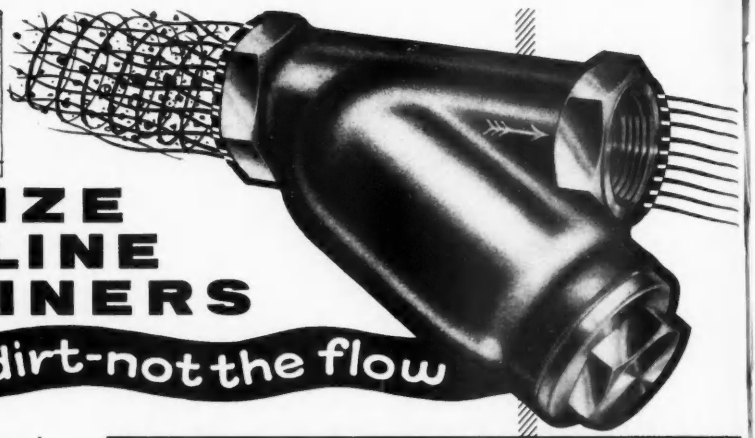

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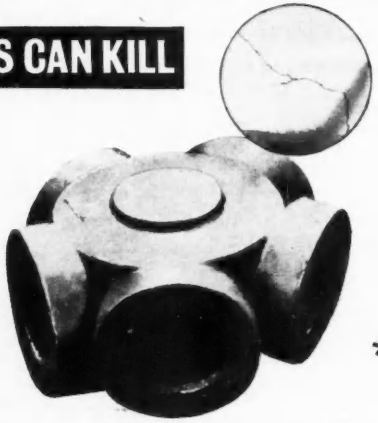

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The machine used was the mobile LB 124 which operates on the Current Flow method.

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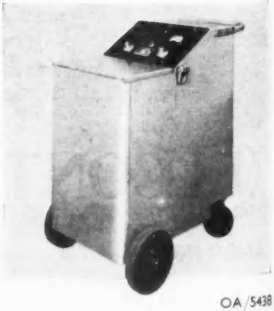

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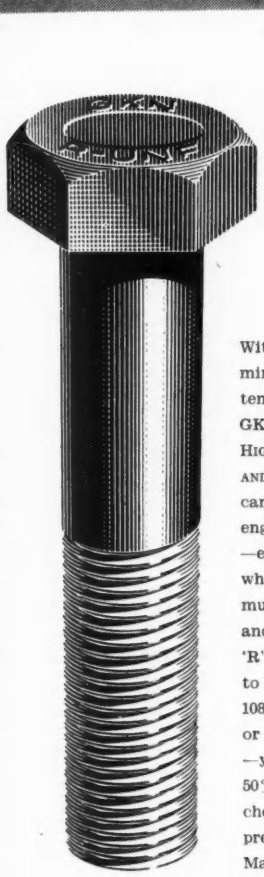

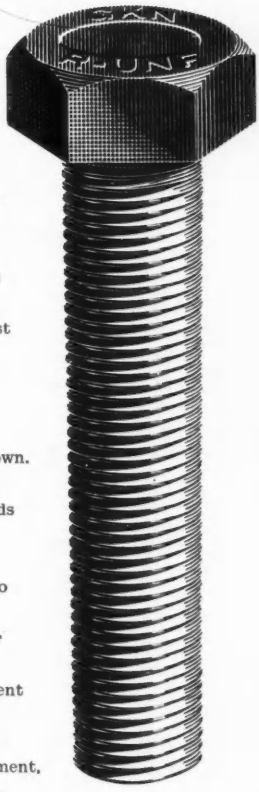

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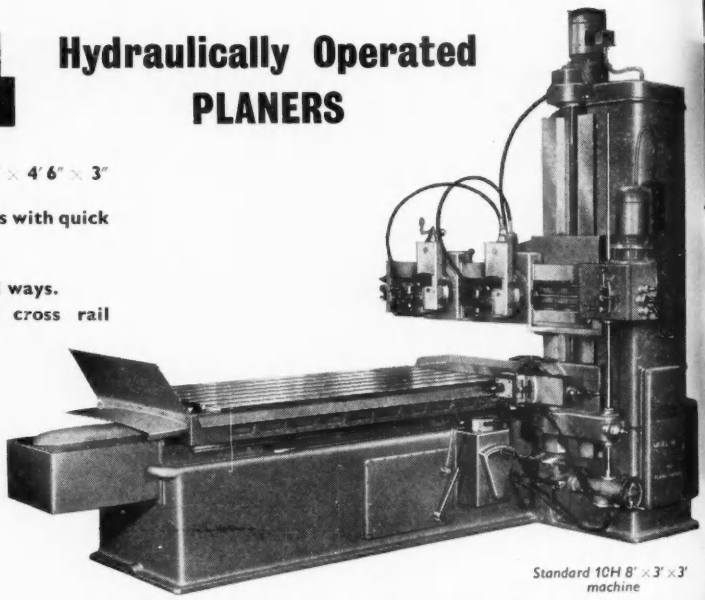

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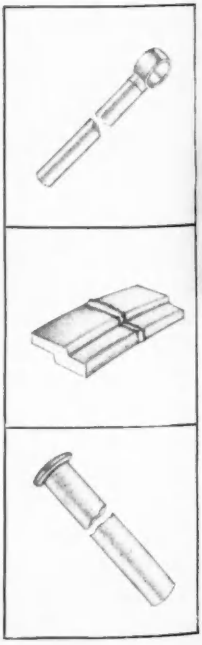

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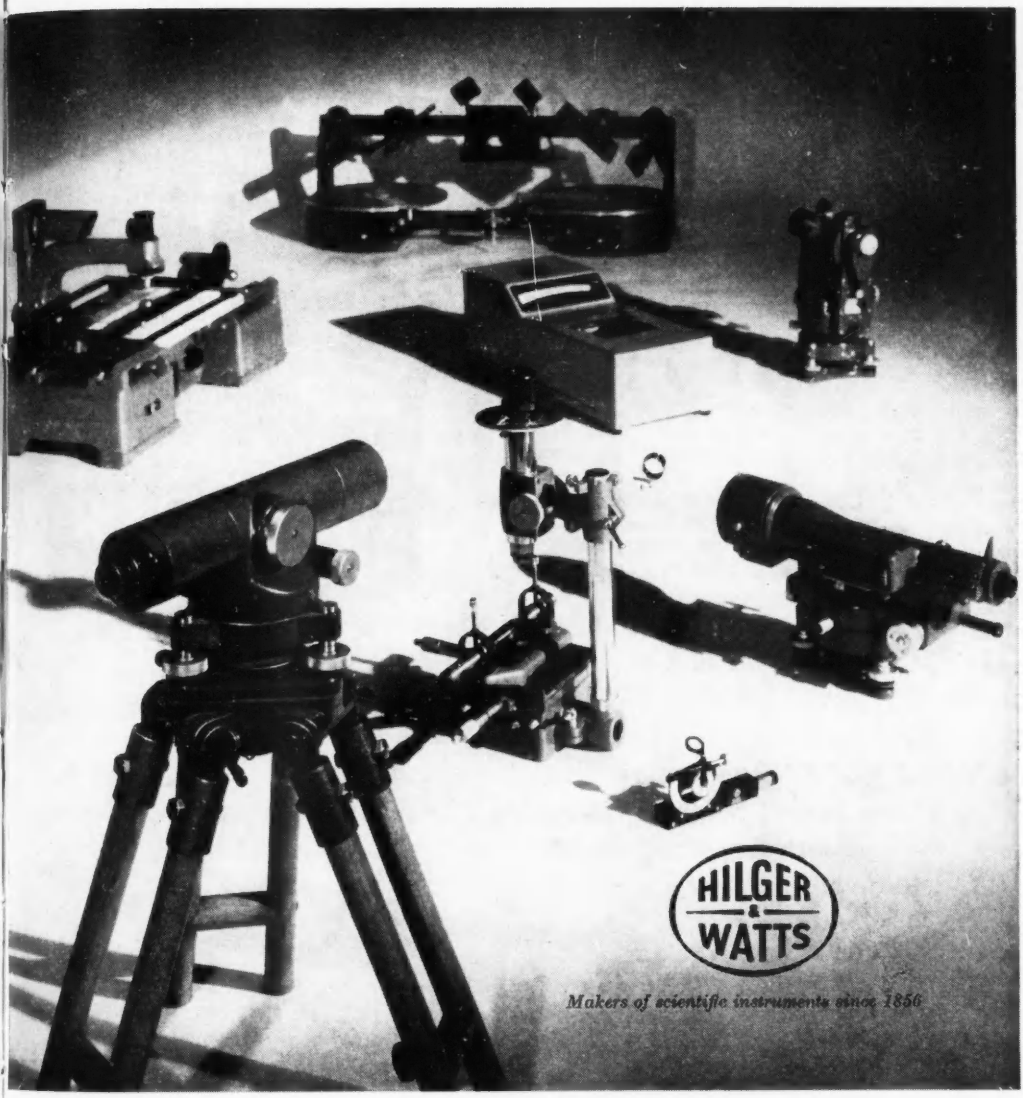

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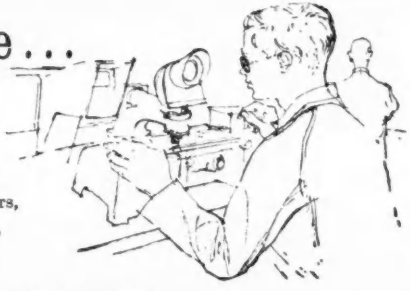

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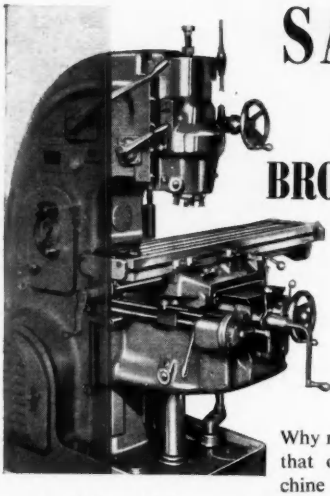

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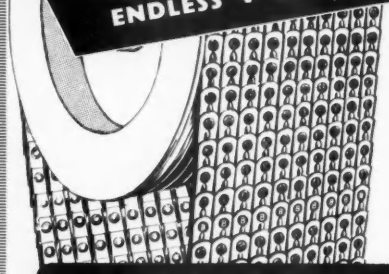

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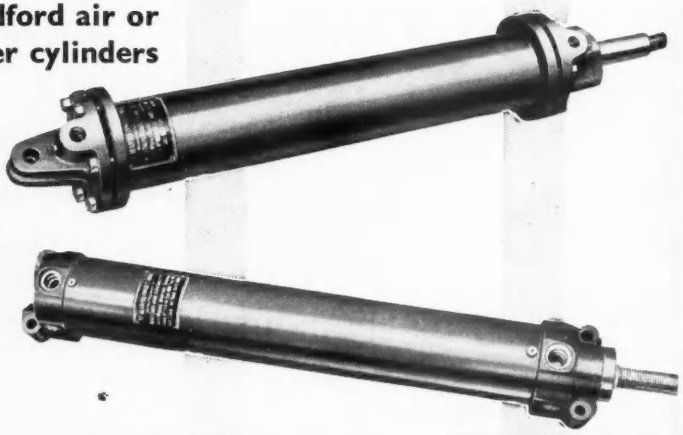

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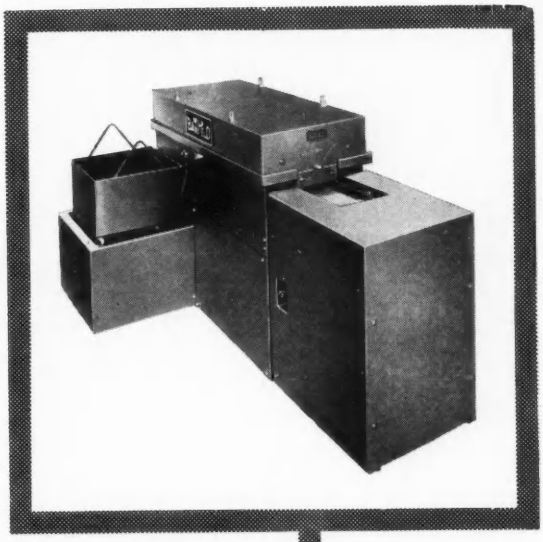

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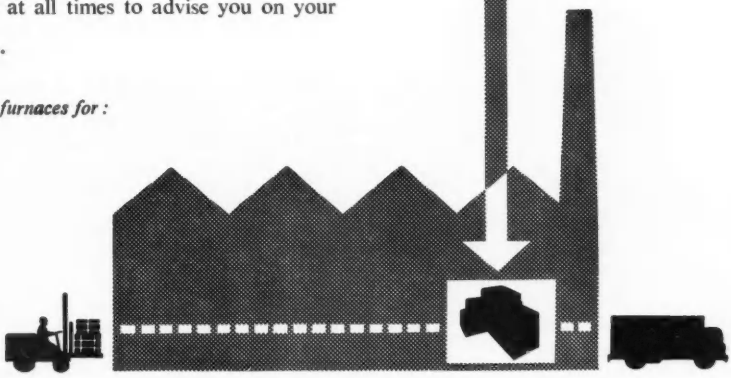

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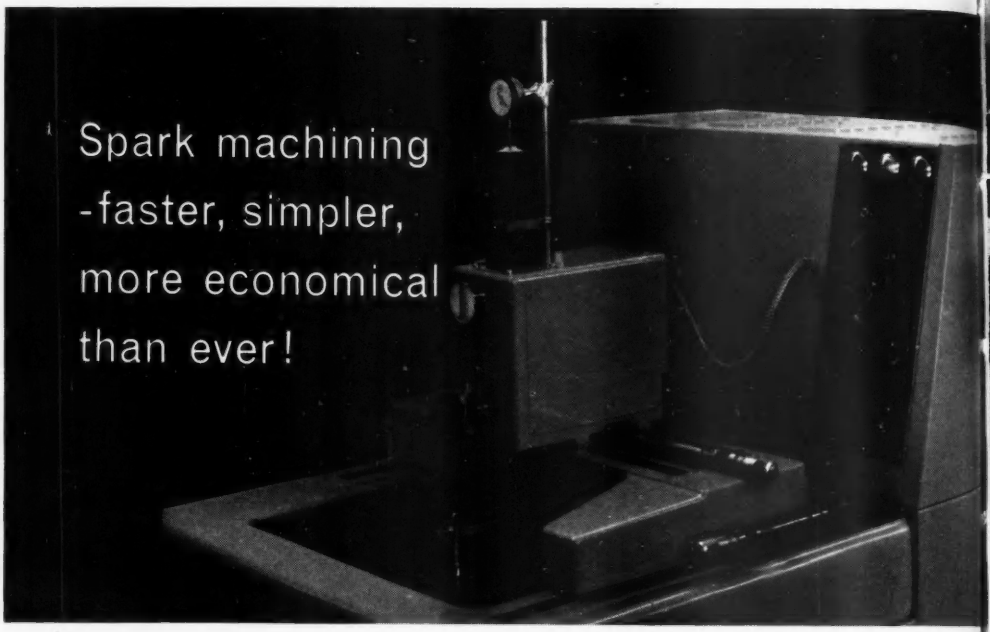

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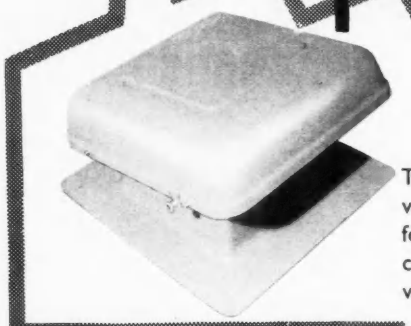

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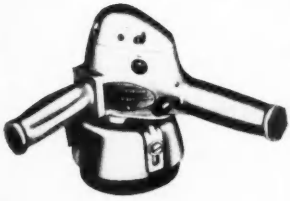

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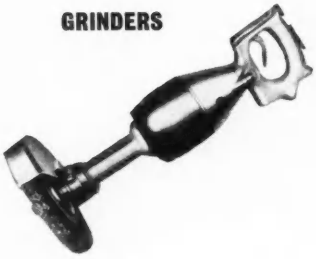

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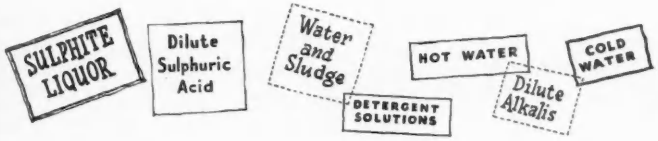

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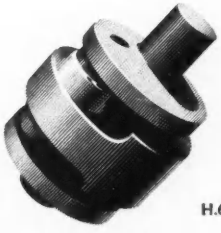

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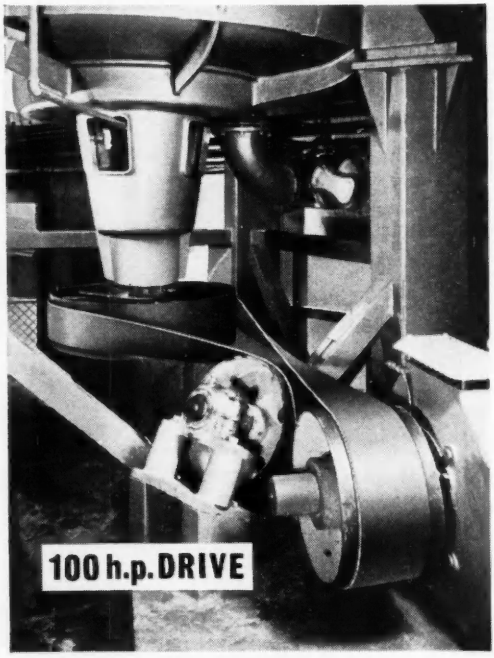

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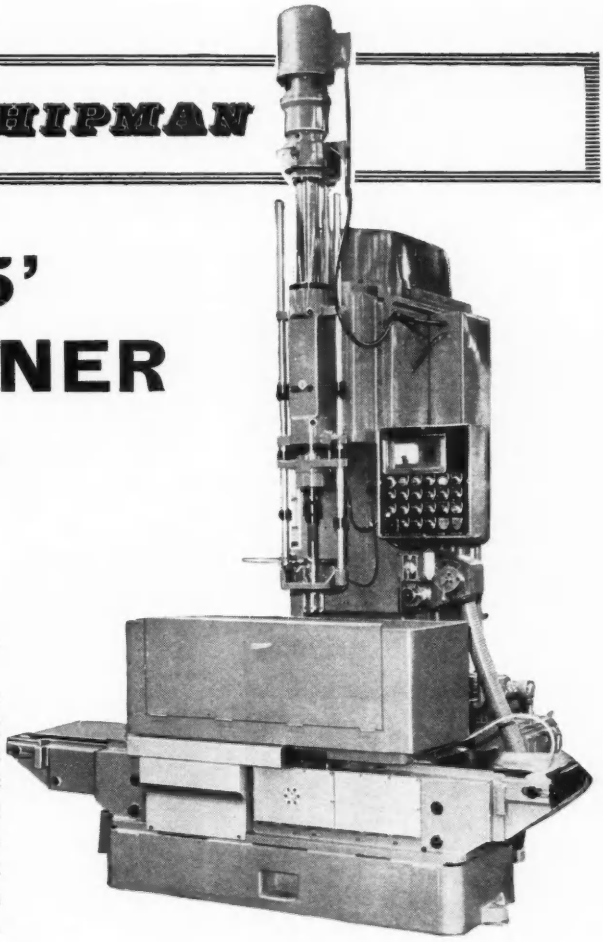

A TYPICAL INSTALLATION ▶

The Model 715 Hydrohoner is now being used in a number of works for honing cylinder blocks. The arrangement using a single spindle machine with automatic indexing table is proving most economical and efficient. The machine shown on this page is installed at Jaguar Cars Ltd., and the honing cycle for six complete bores in a cylinder block, removing approx. .0015 in. stock, is two minutes. The machine is fitted with automatic gauge ring type sizing.

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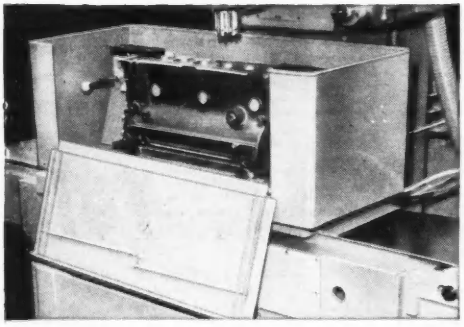

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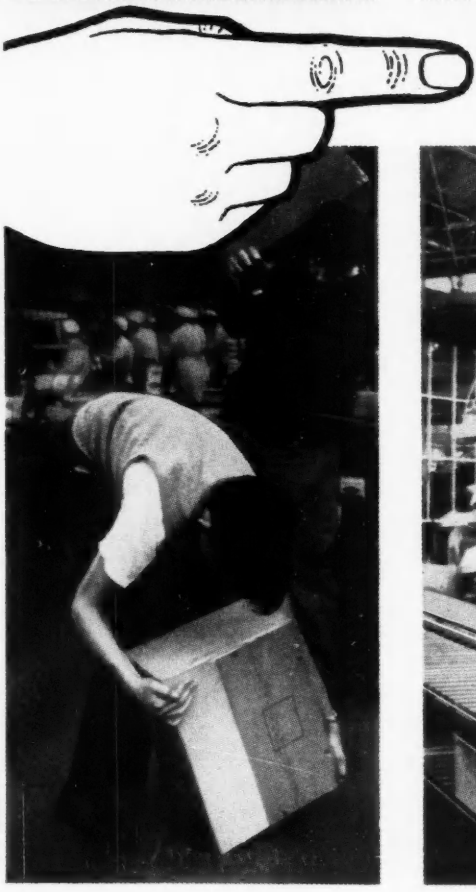

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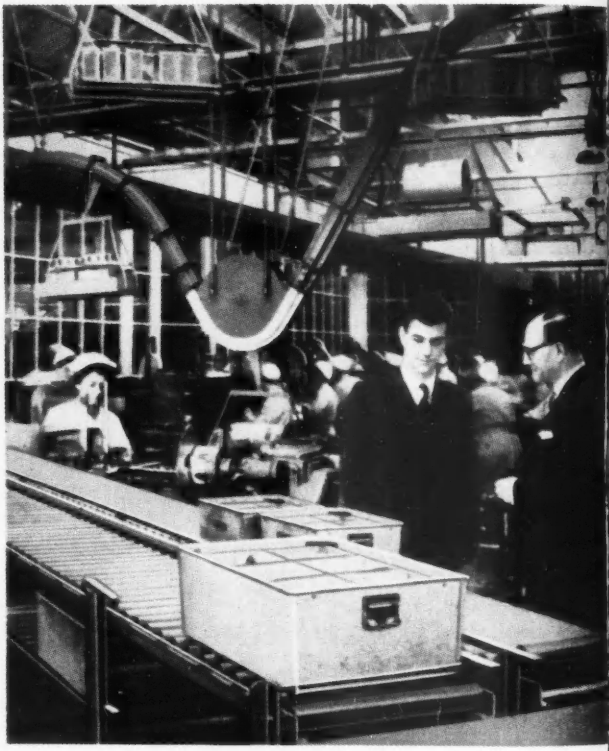

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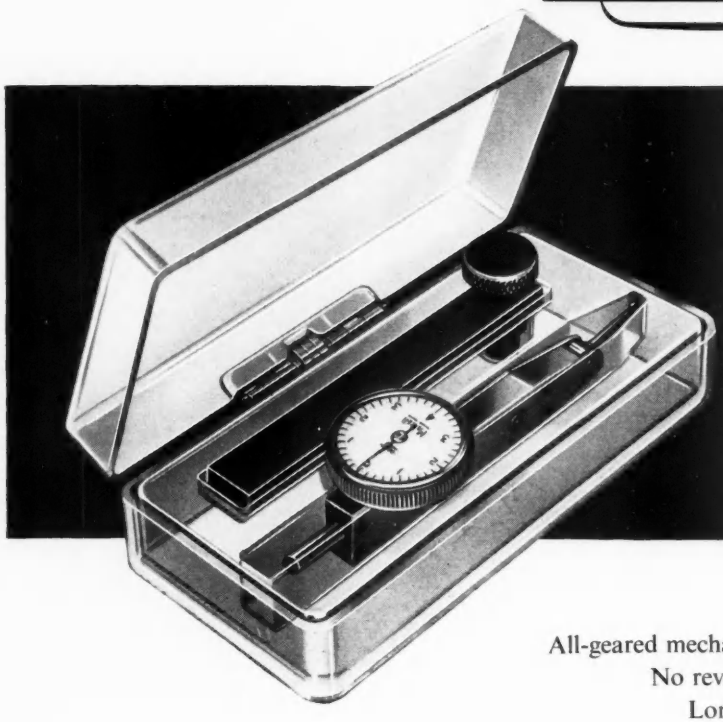

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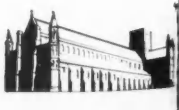

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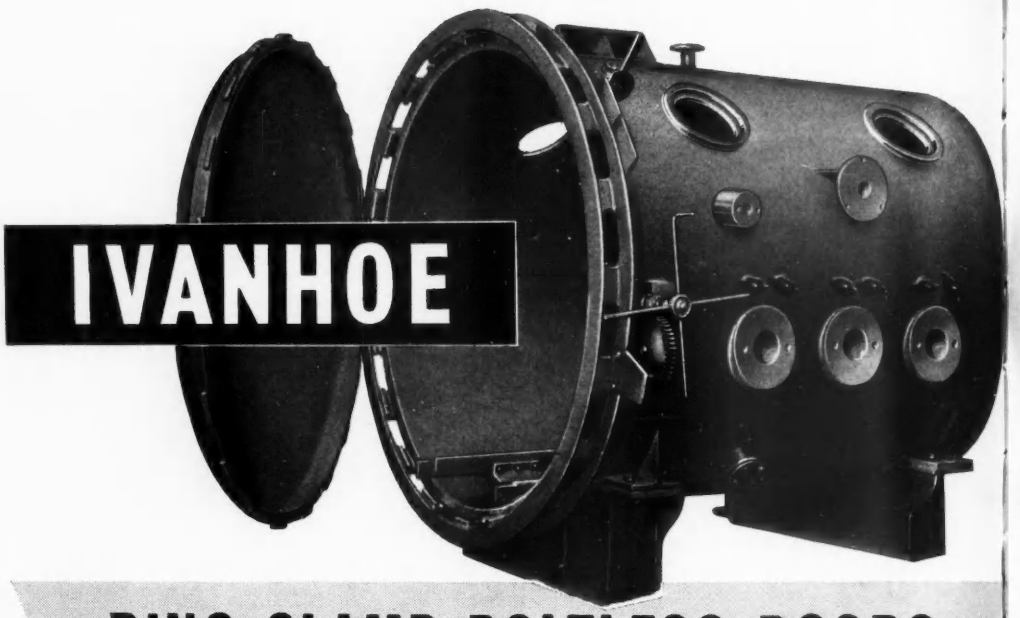
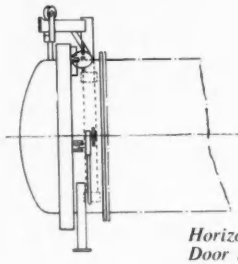


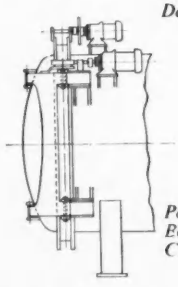
IVANHOE

RING CLAMP BOLTLESS DOORS

for vacuum and pressure vessels



Horizontal Vessel Door moved by side Davit.



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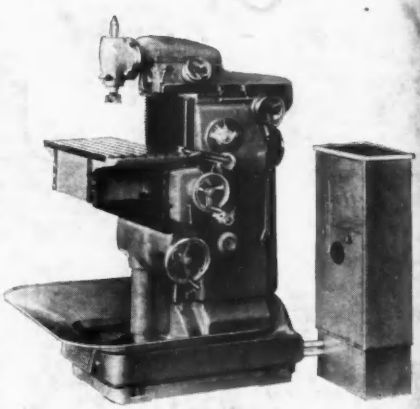
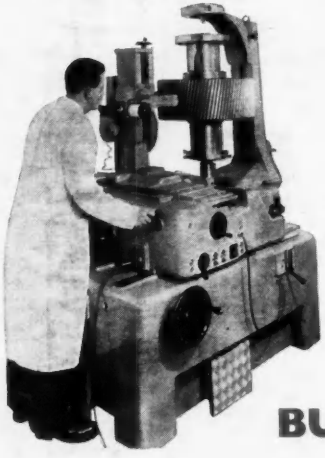


DECKEL OPTICAL CO-ORDINATE MACHINES

Standardised interchangeable units permit one and the same basic machine to be employed for boring, grinding and measuring to a high degree of accuracy. Optical co-ordinate worktable has settings directly and easily read from screens with co-ordinate measuring recticule (accuracy of adjustment 0.00012 in.). Bracket for the interchangeable heads is designed to compensate the effects of thermal expansion.

ABRASIVE (U.S.A.) — Vertical and Horizontal Surface Grinders. **ACKWORTHIE** (Britain) — Drilling and Marking Machines. **BECHE & GROHS** (Germany) — Compressed Air and Steam Hammers. **BERNINGHAUS** (Germany) — Power Presses, Embossing Presses, Forging Presses. **BILZ** (Germany) — Special Purpose Tapping Chucks. **BLANCHARD** (U.S.A.) — Rotary Table Surface Grinders. **BLOHM** (Germany) — Bench Millers, Surface Grinders. **BOLEY** (Germany) — Superfine Turning Machines. **B.S.A. TOOLS DIVISION** (Britain) — Single and Multi-spindle Automatic Bar and Chucking Machines, Centreless Grinders, Lathes, Thread and Form Generators, Broaching Machines, Small Tools, Broaches, Limit Switches. **CINCINNATI-GILBERT** (U.S.A.) — Horizontal Borers, Radial Drills. **CLIMAX** (Germany) — Pipe Benders. **DECKEL** (Germany) — Die Sinking, Engraving, Pantograph and Profile Milling Machines, Tool Grinders. **DELAPENA** (Britain) — Honing Machines. **DETROIT** (U.S.A.) — Broaching Machines. **ERIE** (U.S.A.) — Forging Hammers, Presses. **GREENERD** (U.S.A.) — Arbor Presses. **HANSON WHITNEY** (U.S.A.) — Thread Millers. **HILL ACME** (U.S.A.) — Forging Machines, Surface and Abrasive Belt Grinders. **INFLAGRATOR** (Germany) — Compressed Air Heaters. **KANE & ROACH** (U.S.A.) — Forging Equipment. **KOPP** (Germany) — Controlled Profile and Thread Copy Milling Machines. **KOSTA** (Germany) — Automatic Driving Centres. **MAAG** (Switzerland) — Gear Cutting, Grinding and Testing Machines. **MITTS & MERRILL** (U.S.A.) — Keyseating Machines. **NATIONAL ACME** (U.S.A.) — Multi-spindle Bar and Chucking Machines. **POTTER & JOHNSTON** (U.S.A.) — Automatic Turret Lathes. **PEE-WEE** (Germany) — Thread Rollers. **SCHAUDT** (Germany) — Cylindrical, Internal Cylindrical and Camshaft Grinders. **SCHIESS** (Germany) — Vertical Boring Mills (to 84 ft. table), Horizontal Boring Mills (to 8¼ in. spindles), Milling and Boring Machines (to 16 in. spindles), Crankpin Turning Machines. **SCHULZE & NAUMANN** (Germany) — Plate Shearing Machines. **V. & O.** (U.S.A.) — Power Presses.



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